Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Vol. 12 MARCH, 1956 No. 3

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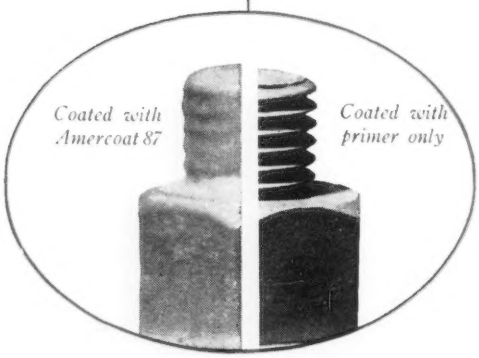

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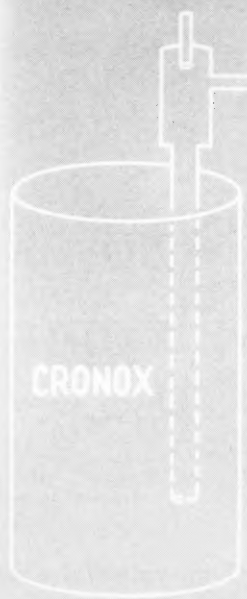

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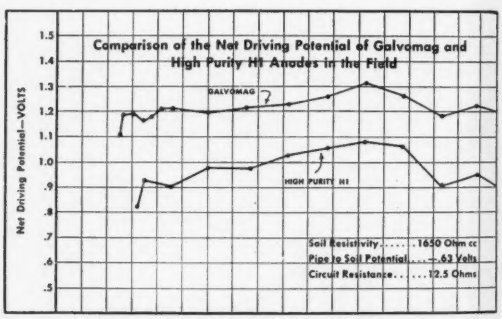

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(Continued on Page 6)

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New vinyl coating easy to use

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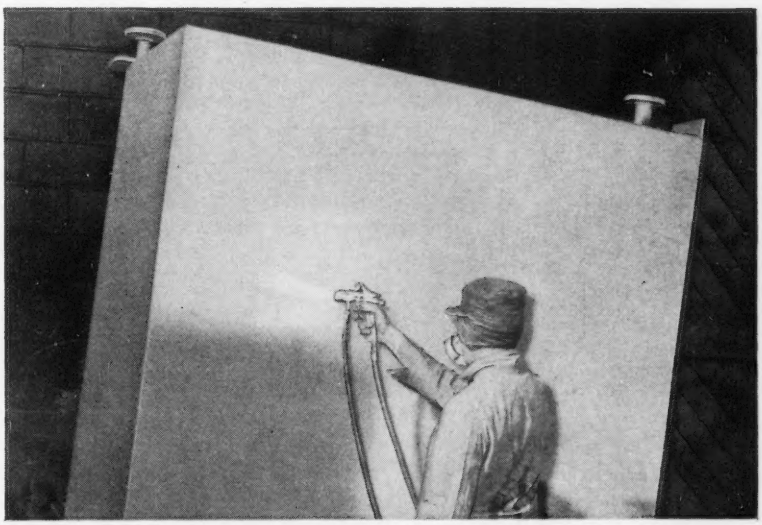

Tank getting a heavy protective coating with Unichrome Plastisol. Large structural parts of products can likewise be durably finished.

A new and unusual plastisol formulation has been developed by United Chromium, a pioneer in this type of coating. Unichrome "Super 5300" Coating delivers the full solids content of vinyl plastisol right through a spray gun. It enables a coat 60 mils or more to be applied successfully in one application.

THICK AND TOUGH

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They give extraordinary protection against a wide range of acids, alkalies, alcohols, salt solutions and moisture. With plastisol protection, ordinary metal parts and products often prove suitable for unusually severe service conditions.

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(Chairman to be appointed)

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• T-5B-5 Corrosion by Molten Salts and Metals

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• *T-5D-1 Questionnaires*

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• *T-5D-3 Inorganic Alkalies*

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• *T-5D-4 Gases*

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• *T-5D-5 Water and Salt Solutions*

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• *T-5D-6 Organic Chemicals*

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(Continued on Page 8)

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(Continued from Page 6)

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Transhield Asbestos Pipe Line Felt meets the need for a felt that is economical yet effective in all ordinary soil conditions.

Designed for easy, high-speed application by modern machine methods, Transhield is strong, light in weight, and highly tear-resistant. Longer length rolls increase application speeds since fewer stops to replace rolls are required. Transhield's highly desirable characteristics are attained through an innovation in felt construction. It consists of a lightweight coal-tar saturated asbestos felt, reinforced with continuous glass yarns parallel-spaced on ¼" centers.

Because Transhield is a continuous membrane between the pipe line enamel and the soil, it works effectively toward preserving a continuous protective film of enamel on the pipe. It guards the enamel during construction and, after installation, it reduces the cold flow of the enamel, acting as a surface barrier to restrict soil stress.

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For further information about Transhield, write to Johns-Manville, Box 60, New York 16, New York; in Canada, 565 Lakeshore Road East, Port Credit, Ontario.

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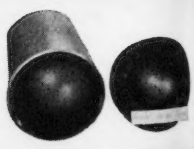

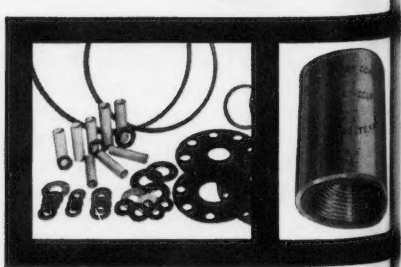

FLANGE INSULATION INSULATED COUPLING

"Precision in

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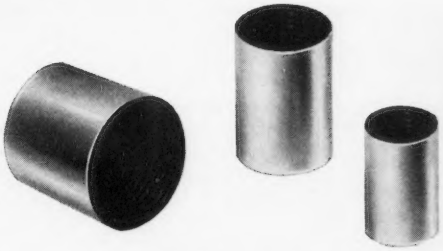
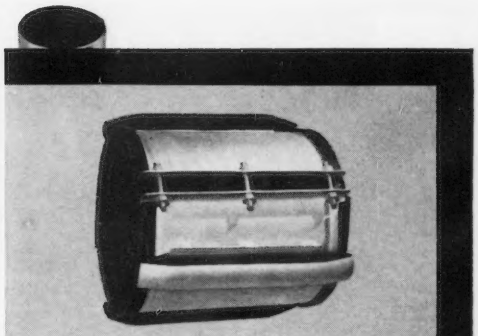
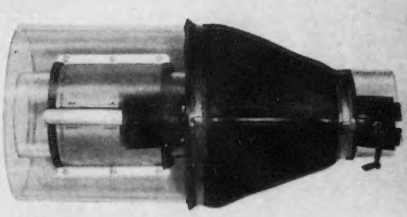


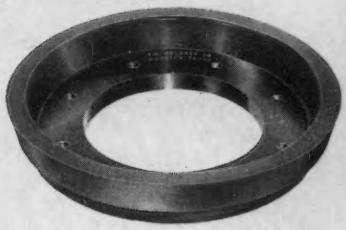
INSULATED COUPLINGS



PIPELINE CROSSING INSULATORS



PIPELINE CASING SEALS



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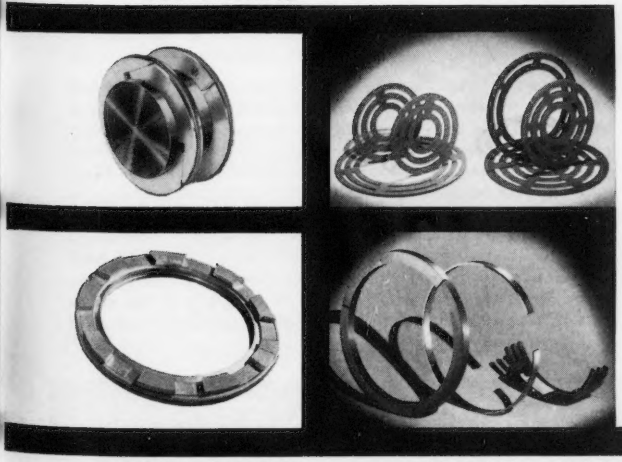

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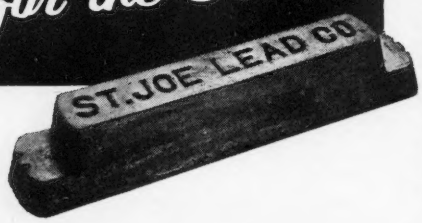

A method of protecting lead-lined vessels under high temperature conditions is to cover the metal with an inner lining of special acid-resistant brick. The installation shown above is a sulfuric acid concentrator, 16 ft. in diameter and 24 ft, high. Some 19 tons of chemical lead were used in lining the vessel. This type of construction is used commonly in the 450°F range and has been used at higher temperatures. The brick lining provides a temperature gradient to insulate the lead. Since no aggregate material can be entirely impervious to seepage, the corrosives leaking through are stopped by the lead lining and thus prevented from destroying the steel supporting structure. *Photo courtesy Chemsteel Construction Co., Inc.*

TYPICAL ANALYSIS OF ST. JOE CHEMICAL LEAD

Silver	.0100%	Arsenic-Antimony-Tin Combined	.0002%
Copper	.06	Cadmium	.0002
Bismuth	Nil	Cobalt & Nickel	.0046
Zinc	.0001	Lead by difference	99.92+
Iron	.0001		

Among the common metals, lead has no equal in its value to the chemical industry as a construction material for handling and controlling corrosives. The metal's utility in this field is well documented by a wealth of available performance records. The protection afforded by lead is the end-result of an inherent chemical property which is unique with the metal. Exposed to most corrosives, lead automatically forms upon its surface an insoluble, tightly adherent film of salts which henceforth acts as an effective barrier against further corrosion. The uncommon property of the common metal lead to forge its own protective armor is the reason why more than one-third of all the lead consumed annually in this country is used primarily for its resistance to corrosion.

St. Joe Chemical Lead is the most extensively used brand of lead in the chemical industries. Hundreds of thousands of tons are now in use—especially where operating conditions are severe. The metal is an exclusive product derived from the huge ore bodies of southeast Missouri which have been owned and operated by this Company since 1865. Owing to the unusual nature of these ores, there is present in the lead smelted from them a combination of copper and small amounts of other elements which produces a grade of lead particularly immune to the attack of most corrosives. At the same time, this natural chemical lead has a lower creep rate and a higher resistance to fatigue failure than lead produced from any other ores.

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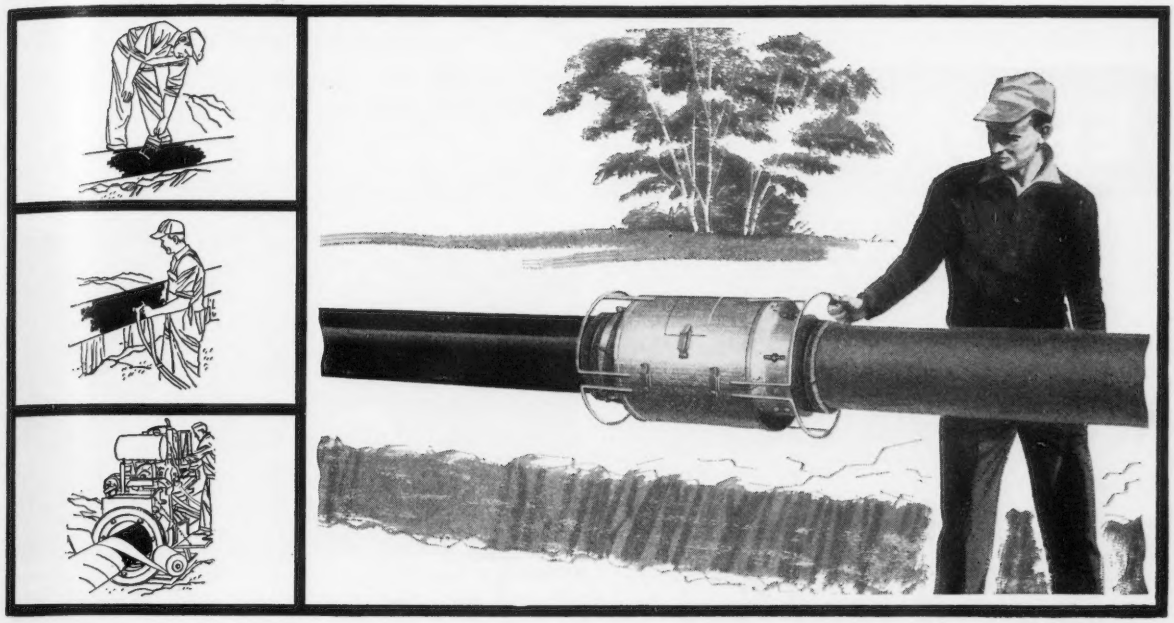

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EASY TO APPLY—FAST DRYING—HIGH ELECTRICAL RESISTIVITY

Because of their ease of application and extremely fast drying time — because they possess the highest electrical resistivity of any cold coating and offer the least amount of objectionable fumes and skin irritants — Roskote pipe mastics have been field approved by more and more leading utilities each year.

In fact, Roskote has been specified by over 200 oil and gas companies for the protection of their natural gas, oil and product pipelines.

A new folder on Roskote, which includes a complete description of its properties, application instructions and full test data, is now available. The test data is of special importance because it gives specific figures on volume resistivity during and after drying.

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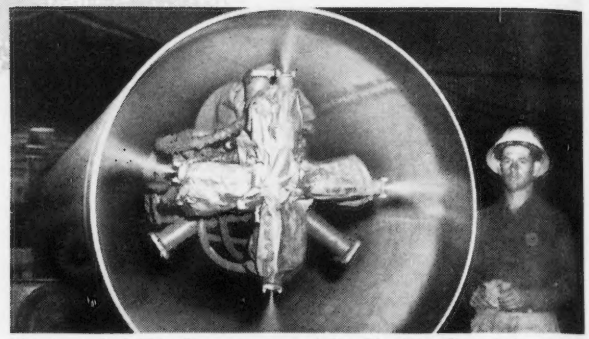
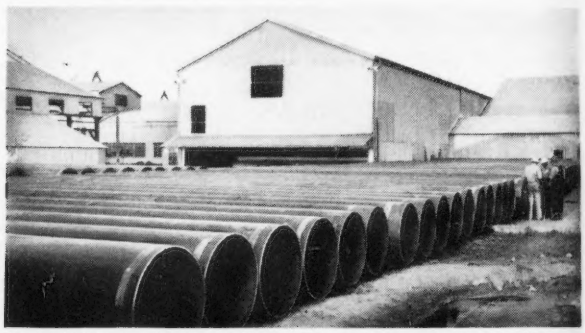
EPON® RESIN does it!

New Internal Coating *protects pipelines against corrosion by crude oil, salt water, gas*



36" pipe to be laid by Transcontinental Gas Pipe Line Corp. being coated with *Copon*, containing Epon resin. *Copon* is manufactured by Coast Paint and Lacquer Co., Houston.



Stock of 36" pipe, lined with Epon resin coating, to be used by Transco.

HERE'S HOW...

INTERNAL CORROSION of gas pipe lines has long been a costly maintenance problem. The solution is an Epon resin coating that stands up to corrosives, that does not flake or peel off, that can be readily applied.

Such an Epon resin-based enamel is now going to work in nearly 300 miles of line for Transcontinental Gas Pipe Line Corp.

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If you need a paint that lasts longer, that has excellent adhesion, resistance to abrasion and impact, ability to withstand a wide range of temperatures, humidity and corrosive atmospheres . . . ask for *Epon resin coatings.* Call on our sales offices for names of suppliers. Write for the full Epon coatings story in the brochure, "Planning to Paint a Pyramid?"

Epon resins are the epoxy polymers made exclusively by Shell Chemical Corporation.

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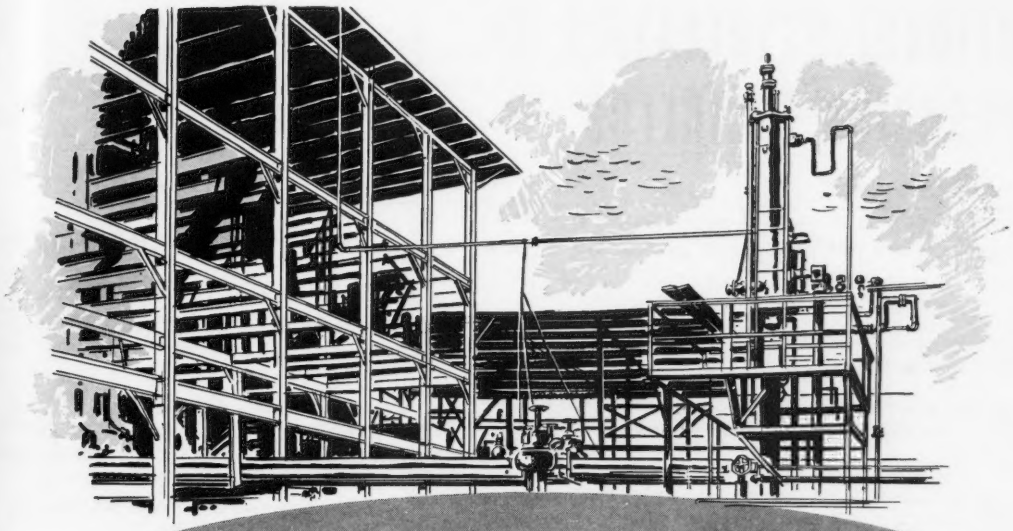

COPON

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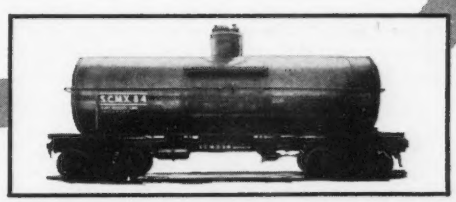
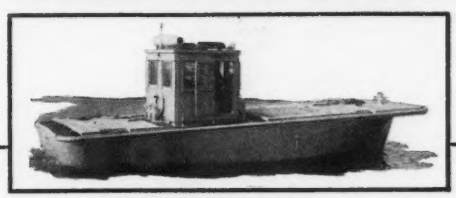
Protect your valuable equipment with **COPON**— *the revolutionary coating that takes unbelievable abuse*

- It gives positive protection against rust and corrosion, also caustics, chemicals, solvents and the destructive action of salt and fresh water.
- It has exceptional tenacity, will adhere to metal surfaces longer and under more difficult conditions than any other coating yet tested.
- It is abrasion-resistant and has proven low erosion rate.
- It has amazing flexibility and elasticity.
- It provides a silky smooth, even surface.
- It is easy to apply by spray, brush or roller coating method.



This tank car is Copon-coated both inside and out to protect it from the ravages of rust and corrosion.



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(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of memberships, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

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Topic of the Month

An Anomaly in Pipe Line Corrosion Diagnosis

By L. P. SUDRABIN*

IN A MIDWESTERN refinery, complete penetration of a 400-foot long 4-inch hot water (170 F) line occurred within two years in several sand backfilled areas. The attack was not so evident on the pipes in areas backfilled with loam-cinders.

The initial observations made are given in Table 1.

The pipe to reference electrode potentials remained steady and no potential gradient effects related to stray current were noted. The line currents measured did not account for the intense attack in the sand areas. Why was it then that the attack occurred primarily on the cathodic area?

The investigation was continued by removing samples of the crust of corrosion product and soil adhering to the pipe on representative areas and examining them. Findings are given in Table 2.

The author has observed that mill scale and rust scale removed from alternately exposed and submerged fresh water flumes and diesel engine liners have shown a potential of + .1 volt measured against a copper sulfate reference electrode. The same thing has been observed for tanker cargo and sea water ballast compartments.

This development has a bearing on the case in question. It is felt that the porosity of the sand allowed alternate immersion and exposure to air on the hot pipe surface, resulting in rust scale (magnetic iron oxide) formation. This highly cathodic iron oxide scale, loosely attached to the underlying bare metal, supports an intense local action corrosion cell.

The loam cinder backfill, being less porous, tends to maintain a more uniform vapor environment around the heated pipe and thus retards the formation of the highly cathodic magnetic oxide scale.

It is hoped that this example of unusual observations in a pipe line survey will remind the Corrosion Engineer to beware of a diagnosis based upon too little information.

TABLE 1—Initial Observations in Pipe Line Survey

Observation	Leak Area	Non-Leaking Area
Backfill	Sand	Loam-Cinders
Resistivity (ohm-cm)	3,000—10,000	2,300—10,000
Potential of pipe to $CuSO_4$ Reference electrode on ground over pipe	—.05 to —.10 V.	—.5 to —.6 V
Pipe Line current	<.4 amps.	<.4 amps.

TABLE 2—Later Observations in Pipe Line Survey

Observation	Leak Area	Non-Leaking Area
Appearance	Red coating on blackened 3/8 inch sand crust	White powder (insoluble) in 1/2 inch thick loam-cinder crust
pH of distilled water extract	8.2	5.15
Response to magnet	Highly Magnetic	Slightly Magnetic
Reaction with dilute HCl	CO_2 gas evolved	No gas evolved; white powder insoluble

* Electro Rust-Proofing Corporation, Belleville, New Jersey.

TECHNICAL PAPERS ON CORROSION WELCOMED

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

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Navy Experimental Work with Cathodic Protection*

By IRVING D. GESSOW*

Abstract

An account is given of work done by the Navy Bureau of Ships with cathodic protection of active and reserve ships. Because it is difficult to dissociate costs for maintenance and corrosion protection it is impossible to say whether or not the cost of cathodic protection of active ships is merited. Because corrosion damage to hulls seldom is considered except when perforations occur, or in destroyers and submarines where plates are thinner and original dimensions more critical, there is some belief that cathodic protection for all ships cannot be justified on a cost basis.

With inactive ships, however, the reverse is true. Indefinite extension of drydocking times, the interval contingent on the exhaustion of anti-fouling paints, is anticipated. Initial cost of cathodic protection of active destroyers, submarines, and five types of reserve ships is tabulated. Details of cathodic protection systems for reserve ships are given. Criteria of protection differ somewhat from the accepted standards. In polluted waters inactive ships may require a potential in excess of 1 volt, while in other high resistivity waters 0.85 to 0.95 volts are sufficient. Some data are given on the cathodic protection of active ships. Merits of sacrificial anodes versus impressed current are listed. Extensive further activity in cathodically protecting active ships is contingent on the outcome of trials now under way.

Introduction

THE BUREAU OF SHIPS within the past six years has made a significant increase in the use of cathodic protection in both the active and reserve fleets of the United States Navy. This expansion was encouraged by the success of the initial installations sponsored by the Bureau and by the parallel successes in the commercial maritime industry, in the United States Maritime Administration, and in the Canadian Navy.

Some explanation of the function of the Bureau of Ships within the Navy may be helpful. The management of the Navy below the levels of the Secretary and the Chief of Naval Operations is divided among several Bureaus, each corresponding to the major functional supports for the fleet. These Bureaus are as follows: Personnel, Supplies and Accounts, Ships, Ordnance, Yards and Docks, and Medicine and Surgery.

The fleet itself is a direct responsibility of the Chief of Naval Operations. The Bureau of Ships designs, builds, and maintains the ships of the fleet. The cathodic protection program is a small part of this maintenance function. The Bureau of Yards and Docks has a complementary program to protect floating drydocks and submerged shore structures.

Distribution and Intensity of Underwater Corrosion.

The underwater paints used by the Navy[1] are known to be sufficiently durable so that an active ship need not be redocked for renewal of underwater paint for at least two years; a reserve fleet ship need not be docked for at least five years. At these dockings light corrosion is usually found along the waterline and plate sight edges; it also is found scattered about the ship where the paint has failed, as in the way of anchor chains.

On active ships light to severe pitting is usually found on struts, shafts, rudders, rudder skegs, shaft bearing tubes, and on hull areas in way of keel blocks. Replacement of hull plating caused by such corrosion is rarely, if ever, done, despite the fact that no corrosion allowance is provided on the plating of Navy ships. Occasionally, heavy pitting severe enough to penetrate the hull, occurs (Figure 1). In these instances plating is replaced only if there is extensive damage which cannot be economically repaired by welding.

Paint renewal is not, however, the only reason for docking. Examination, repair, or replacement is made on sonar gear, shaft bearings, propellers, stern tubes, fairwaters, rope guards, and bilge keels. In addition, bearing clearances are always verified. Occasionally, collision damage is repaired. Inasmuch as the cost of repairing the minor corrosion is lost in the foregoing work and in surface preparation for painting, it must be estimated that the annual cost of corrosion of the hull forward of the shafts is small indeed.

The observation that the cost of hull corrosion is small does not apply to submarines. Submarine superstructure is complex and inaccessible for routine maintenance unless much structure is removed. Drainage is poor and the alternate wetting and drying as the ship is submerged and surfaced rapidly accelerates corrosion.

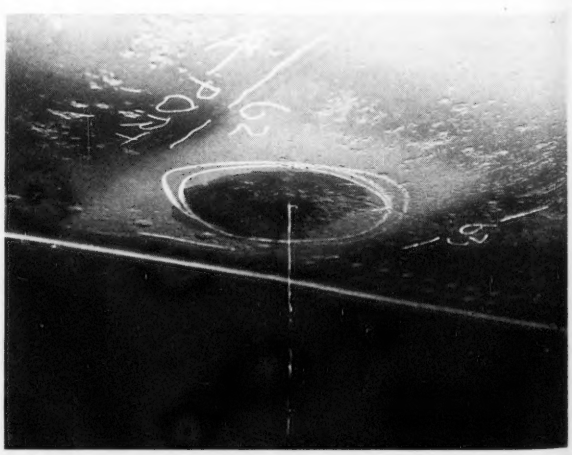

Figure 1—Pitting of shell below waterline. Depth of pits ranged from ⅛ inch to thickness of plating (5/16 inch). Pitted sections were cut out and replaced. Cathodic protection was installed to prevent such pitting.

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* Department of the Navy, Bureau of Ships, Washington, D. C.

(1) These paints consist of several formulations of hot melts, conventional solvent solutions of resins, and vinyl resin paints.

Corrosion Affected by Cathodic Protection

Corrosion in the stern areas of all ships and particularly high speed ships is serious and frequently leads to expensive replacement of propeller shaft struts and rudders. To the author's knowledge it has not been determined whether the pitting is caused by mechanical or electrochemical means. While the cathodically protected ships which have been docked so far indicate that the seriousness of this corrosion may be less than for unprotected ships, the evidence is not conclusive. Additional laboratory work in this connection is planned.

The occasional deep pitting in the forward parts of ship hulls can rarely be traced to any specific causes. If attributed to a large cathode-small anode relationship, then cathodic protection may prevent the condition. If it is caused by improper welding line arrangement, as can and does frequently occur, then cathodic protection will be of little assistance, except for indicating the existence of a wrong hook-up.

Value of Cathodic Protection

The following conclusions can be made regarding cathodic protection:

1. Underwater corrosion of the forward part of the hull is normally not serious when a good paint system is used. Its cost cannot be estimated but it does not represent a significant separate element of cost. For active ships a properly designed cathodic protection system will, however, virtually eliminate this corrosion and the expenditures associated with it.
2. Certain unexplained incidences of heavy hull corrosion frequently occur in the forward part of a hull. It is likely but not statistically certain that cathodic protection will prevent this corrosion.
3. Corrosion of struts, shaft tubes, and rudder assemblies may be reduced by cathodic protection, but verification of this indication is necessary. At present, prevention of corrosion of these fittings is not a reason for routine installation of cathodic protection.
4. The foregoing conclusions indicate that the docking of a cathodically protected active ship probably could be extended with confidence several additional months. A cathodically protected reserve fleet ship on which turbulence in the stern area is no problem, could have its docking interval extended several years.

Cost of Cathodic Protection

Now that the scope of application of cathodic protection has been discussed it is appropriate to consider the question of cost. This factor will depend of course on the design used. A brief cost resume is shown in Table 1. It should be regarded only as indicating the magnitude of labor, material, and overhead costs of unfamiliar experimental applications in naval shipyards. Estimated annual costs are not given because the author has not had enough experience as yet with these systems to calculate a fair annual cost.

Most of the foregoing costs are for labor. The figures become inflated when work is done on an unfamiliar project. (It was necessary to make the installations described in four different shipyards.)

For inactive ships the available costs for materials are known (see Table 2) but labor and overhead costs are not known because the work is being done by enlisted personnel assigned to the reserve fleet for training.[2] The costs are all for impressed current systems with graphite anodes.

For the inactive fleet the conclusion is clear: For the increased years between dockings which cathodic protection will permit, the cost of protection is negligible. Its use in the reserve fleet in both salt and fresh water locations is justified.

For the active fleet no clear conclusions can be set down. The initial installations have been expensive and even though the costs will be reduced as experience accumulates, the cost will still be high. The concept of self-insurance also enters here. Hull corrosion costs which could be prevented by cathodic protection are infrequently very high (as much as $100,000 per destroyer, not counting the loss in operational availability). Yet, it might be economical to accept this instead of installing cathodic protection on every active ship at a greater total cost.

TABLE 1—Cost of Experimental Cathodic Protection Installations for Active Ships

Ship	Underwater Area in Square Feet	Anodes	Initial Cost in Dollars
Destroyer	20,000	Controlled magnesium	8000[1]
Destroyer	20,000	Uncontrolled magnesium	3000
Destroyer	20,000	Graphite	8000[1]
Destroyer	20,000	Platinum-coated rod	8000[1]
Submarine	13,000	Platinum-coated rod	17000[1,2]
Submarine	13,000	Controlled magnesium	18000[1,2]
Landing Ship	17,000	Uncontrolled magnesium	5000

[1] Cost high because of hull penetrations at each anode.
[2] Cost high because of hull penetrations at each reference electrode.

Reserve Fleet Installations

At present approximately 125 ships in ten reserve fleet sites along both the east and west coast are under protection and installation work is underway on approximately 430 more ships. Although these initial installations are being made in sites which are essentially salt water (conductivities ranging from 25 to 100 ohm-centimeters) it is planned that protection will be installed at the more inland sites with water conductivities up to 5000 ohm-centimeters.

Installation Features

An impressed current system was selected for the reserve fleet after initial trial installations of both sacrificial and impressed current systems were made. The impressed current system is more suited for waters of high resistance than the magnesium and also represents a more permanent installation. While the installation of the impressed current system is

[2] The totals shown, however, are believed to be fair approximations for total installation cost by commercial activities.

TABLE 2—Cost of Cathodic Protection for Inactive Ships

Ship	Underwater Area in Square Feet	Cost in Dollars
Destroyer	20,000	600
Tug	9,000	600
Cruiser	47,000	1300
Transport	33,000	1000
Carrier	85,000	2100

more expensive, the units, once installed, require no attention except for easily made current adjustments which affect each anode. Current adjustment for magnesium anodes requires lifting anodes out of the water which means that small variations in current are more difficult to achieve.

The usual procedure is to consider one nest of ships as a unit. A nest consists of one to four ships moored parallel to each other on the same side of a pier and separated only by wood fenders at a distance from five to ten feet. One rectifier of sufficient capacity to provide three milliamperes per square foot of total underwater surface per nest is mounted on one ship and all are electrically bonded together. If additional current capacity is needed two rectifiers with output connected in parallel are installed.

Graphite anodes in the form of cylinders 3 inches in diameter and 60 inches long equally spaced about each ship are used. They are provided on the basis that two milliamperes of protective current will be required per square foot of protected underwater surface and that maximum current capacity is 8 amperes per anode in water less than 500 ohm-centimeters and 5 amperes in greater resistivity water. The difference is established to obtain improved current distribution in the higher resistance water by providing more anodes. The smaller current output also decreases oxygen evolution at each anode and prolongs its life in fresh water sites.

The current required for hulls of different sizes in different waters is shown in Table 3 for representative ships.

Differences in current requirements are caused by variations in the condition of the paint on the hulls. It will be noted that large currents are provided at low driving voltages in low resistivity water while higher voltages are necessary in high resistance water. Fortunately, no large ships with high current demands are berthed in fresh water sites.

Protection Achieved

In the course of the experimental work leading to the adoption of cathodic protection approximately 25 ships were docked one and two years after installation of protection. The systems on groups of these ships varied as did the paint conditions which ranged from newly painted to paint five and six years old.

TABLE 3—Typical Current Requirements for Inactive Ships.

Sites	Usual Water Resistance ohm-cm	Approx. Area in Square Feet	Rectifier Setting	
			DC Voltage	DC Current (Amperes)
Norfolk	35	2000	2	2
Norfolk	35	33000	4	10[1]
Norfolk	35	33000	9	45[1]
New London	35	13000	3	5 to 15
New York	35	85000	15	55
Boston	25	47000	3	24
Charleston	35	17000	4	15 to 20
San Francisco	35	58000	3	35
Columbia River	5000	7000	5.5	.75
Florida	1000	.....	2.8	1

[1] Differences due to condition of underwater paint system on different ships.

Several ships in the program initially were sand-blasted completely clean. At these inspections, the conditions of the hulls varied enough to permit the following conclusions:

1. In low resistivity waters (i.e., less than 100 ohm-cms) virtually complete protection can be obtained. The anodes must be equally distributed about the hull and a potential of at least 0.80 to 0.85 volts to a copper sulfate electrode maintained. The current required will depend upon the amount of bare area exposed. It will range up to 10 milliamperes per square foot for a completely bare hull.
2. In high resistivity water (i.e., more than 100 ohm-cms) significant corrosion protection can be obtained at potentials of 0.85 to 0.95 volts with the same number and distribution of anodes as used in low resistivity waters. Improved protection can be obtained by increasing the voltage to 0.95 to 1.05 with anodes spaced at about one-half the intervals used for low resistance water.
3. Cathodic protection will protect the area immediately below the waterline to the same degree as structure deeply submerged.
4. In water which is highly contaminated with sewage or has abnormally high oxygen content it appears that cathodic protection is quite effective although not as much so as in other waters. The Naval Research Laboratory has conducted panel tests to determine corrosion rates at the one site which is particularly troublesome in this respect—San Diego. It appears that a potential above 1.00 volts to a copper sulfate cell is necessary to prevent corrosion in San Diego harbor.
5. It is realized that the desirable potential ranges cited above are higher than those usually cited in the literature. The author's experience would indicate strongly that these ranges will provide greater assurance of protection for ships with a range of paint conditions than will a range of say .80 to .85 volts.

Future Plans

It is intended that the docking interval of cathodically protected reserve fleet ships be increased from five to seven or eight years. Because of the fact that no other underwater work will be performed the savings will be greater than those to be expected from omission of docking and painting.

Even though the normal docking interval will be increased this will not mean that cathodically protected ships will not be docked more frequently. From a readiness standpoint a hull free from fouling is necessary. Inasmuch as cathodic protection does not diminish fouling, and inasmuch as antifouling paints do not remain effective indefinitely, it still may be necessary to dock high priority ships at frequent intervals.

Active Fleet

Work done by the author in the active fleet has been concentrated principally on destroyers and submarines because the greatest repair cost for corrosion damage is incurred on these vessels. (Destroyer plating is thin and perforated shell plates and shaft struts are not unusual. On submarines the area under the superstructure is inaccessible and pitting on any part of the pressure hull cannot be permitted.) Installation of anodes on these ships is limited sharply by the necessity to keep the system weights at a minimum.

Installation Features

Systems are designed on the basis of providing

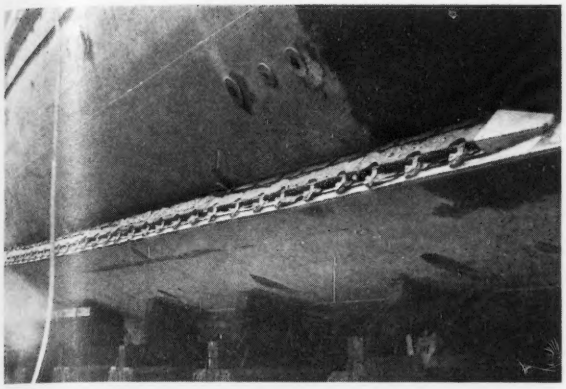

Figure 2—Magnesium anodes with exposed straps after one year of use. Because Navy ships are docked at two year intervals, it is necessary to redesign these anodes to avoid the accelerated metal consumption adjacent to the straps.

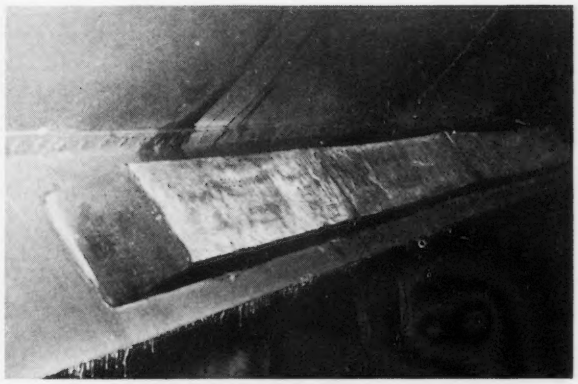

Figure 3—Bilge keel-mounted magnesium anodes secured by cast-in studs and nuts from the underside of the bilge keel. This mounting avoids the accelerated local metal consumption at exposed securing straps which is so characteristic of other magnesium anode designs.

3 milliamperes per square foot of painted underwater surface. This of course represents a much higher current density at bare areas. Examination of the records of protected hulls show that this is approximately the current density drawn by ships at protected potential while underway. This value is practically independent of the ship's speed.

When at rest the current requirement is approximately one-half the underway value. Of the total current at rest approximately one half may be regarded as directed to polarization of the propeller to the potential of unprotected steel, and the remainder to bringing the potential of steel and bronze to the protective range. This approximation was derived by measurement of the current required to bring a painted destroyer hull to protective range in the absence of the two bronze propellers normally fitted. Current readings taken immediately after the propellers were installed gave the figure for the excess current needed for the propellers.

Magnesium Anode Installations. Installation with magnesium anodes in 4-inch by 10-inch by 60-inch and 7-inch by 7-inch by 16-inch sizes have been made on both destroyers and submarines. Two systems have been installed. On one system the current output is metered and controlled by a rheostat within the ship; on the other each anode is electrically connected to the hull by the securing studs. In some of the installations the anodes were installed in a continuous row close to each other on the top of each bilge keel (Figures 2 and 3). In others anodes in groups of three were distributed in six or seven locations about the hull. The conclusions arrived at as a result of these installations are as follows:

1. Ships protected with magnesium anodes after one year are either virtually free from corrosion (Figures 4 and 5) or show only insignificant surface rust, at both forward and stern areas. The same is not true for unprotected ships. This absence of corrosion appears even though hull potential readings during the year show a protective range for only part of the time.

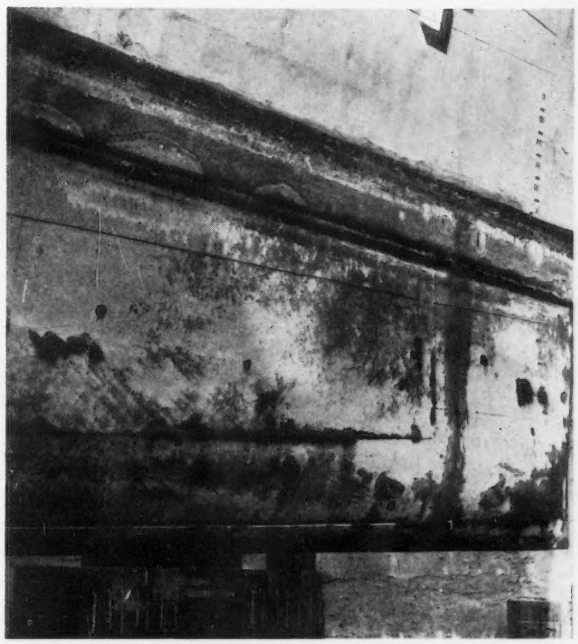

Figure 4—Starboard bow of destroyer after one year of protection with magnesium anodes. Paint failure is typical of destroyer and was not accelerated by protective current. All bare areas were exposed for perhaps six months. Only very superficial rust was present.

2. The consumption of magnesium anodes in moving water is much greater than in still water. The area at which magnesium is consumed is concentrated at the fastenings to the hull, irrespective of anode type (cast-in straps with exposed ends for bolting, or concealed straps with inner, shouldered, cores which are concealed after installation).
3. Some means must be found to prevent this accelerated consumption. Otherwise anodes will not last for more than 12 to 15 months, whether installed in a controlled or uncontrolled system. Because Navy ships are generally docked at two-year intervals, this deficiency limits the use of magnesium. (Trials with various paint systems on anodes to overcome this are underway.)

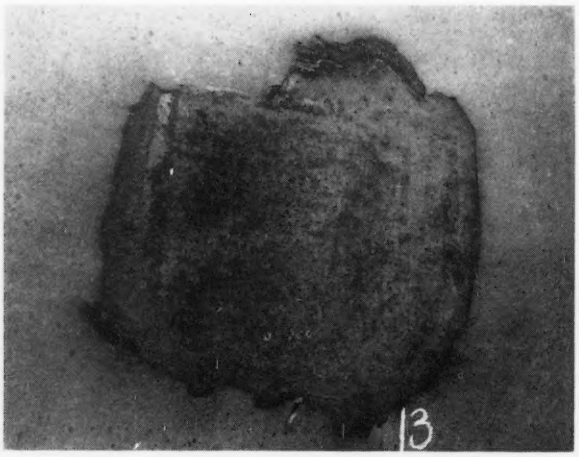

Figure 5—Close-up of bare test area after one year in water under cathodic protection by magnesium anodes. There was virtually no rust on the surface.

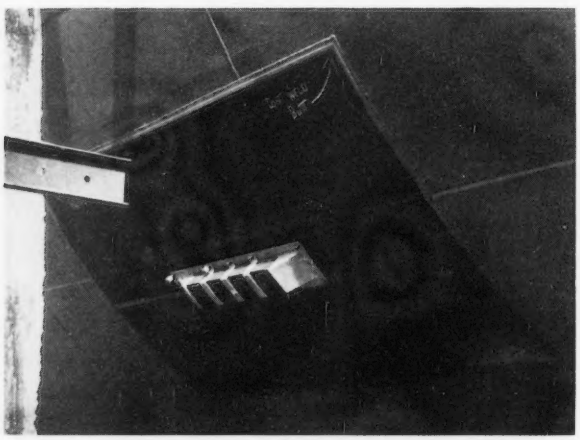

Figure 7—Experimental 3 by 6 by 30-inch graphite anode on a destroyer. The mount is of molded polyester-glass. Anode assembly is mounted over a 6-foot by 10-foot by 1/16-inch neoprene rubber shield cemented to the hull.

4. Installation of anodes on the bilge keel alone is not as satisfactory as distributing anodes in groups about the hull with 50 to 60 percent of the anodes in the aft third of the hull. Because anodes are easily attached to the bilge keel a good economical arrangement would be to install the forward anodes on the bilge keel and the remainder just forward of the propellers.

Graphite Anodes. Although five destroyers have been fitted with graphite anodes they are all recent installations and it is not possible as yet to judge their efficiency. Two anode shapes are used: graphite rods 3 inches by 60 inches as used for the reserve fleet (see Figure 6) and blocks 3 by 6 by 30 inches (see Figure 7). All are controlled systems with current fed from a rectifier to several anode groups.

Platinum-Clad Anodes. One destroyer and one submarine have been fitted with platinum anodes mounted in insulated holders (Figure 8). Each anode consists

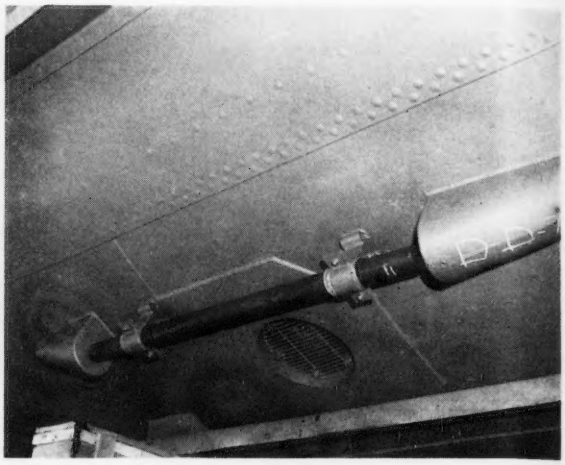

Figure 6—Experimental 3-inch diameter by 60-inch long graphite anode used on an active destroyer. The fairwaters shown were later removed. For reserve fleet use the same anodes are suspended vertically over the ship's side.

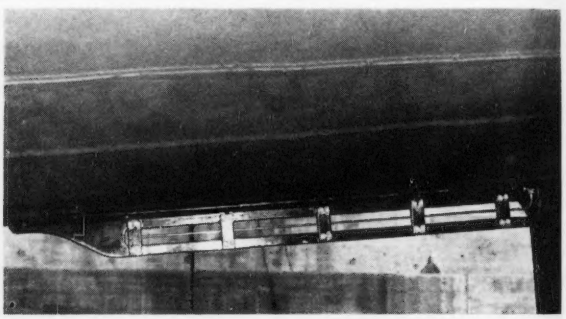

Figure 8—Platinum-clad anode on active destroyer. Seven anodes of this type, each capable of delivering 15 amperes from one central rectifier, have been installed recently on a destroyer.

of a 50-inch long silver alloy rod ¼-inch in diameter and clad with a 5 mil thickness of platinum alloy. The submarine installation has been inspected once and appears to be very successful. The destroyer installation is very recent and has not been put into operation.

Aluminum and Zinc Anodes. Both aluminum and zinc anodes have been tried. Aluminum alloy rods were installed under the superstructure of a submarine and appeared to have been fairly successful in reducing corrosion until they were removed during some repair work. They may be particularly useful in submarines because the low potential may prevent the high alkalinity anticipated with magnesium anodes. (This alkalinity is undesirable because the conning tower fairwaters are of aluminum.)

High purity zinc anodes were installed on a small tug. Readings over the past year indicate that the hull has been completely protected. The author hopes to make more installations of both aluminum and zinc anodes. This will be particularly true if current trials indicate that throwing power of the anodes in sea water will be sufficient to provide sufficient current for protection, and if local action, as occurs with magnesium, is less severe.

Sacrificial Anodes Versus Impressed Current

There is much discussion on the relative merits of these systems for shipboard use. Inasmuch as the most common sacrificial anode in shipboard use today is magnesium, it is appropriate to compare it with graphite and platinum.

Weight. The question of weight is very important on naval ships. For 20,000 square feet of underwater surface a magnesium anode installation would weigh at least 2,000 pounds compared to about 800 pounds for an impressed current system.

Durability. Impressed current systems are relatively permanent. Even at best, magnesium anodes would have to be replaced at two-year intervals.

Cost. The initial cost of an impressed current system is two to three times that of a magnesium system. This cost is due largely to the need for penetrating the hull at six or seven locations. However, this cost occurs only once. Maintenance cost would involve only occasional replacement of anodes at a low cost.[3]

Control of Current Output. While control of current output is easier with an impressed current system there is no indication that any control is needed with magnesium anodes. The current output is either constant or drops as the hull potential rises.

Shielding. Equal shielding is required for both types.

Operation. From the standpoint of operation a magnesium anode system appears preferable. An impressed current system, despite its simplicity, is an added chore and one that tends to be neglected. The need for taking potential readings is always there and many times scheduled shipboard exercises interfere. If the automatic controls now being discussed reach the working stage then this objection will no longer exist.

Another consideration is that the stuffing tubes will leak if not properly installed, thereby making it necessary to disconnect the anode. The graphite anodes also do not appear to be as rugged as magnesium and several have been lost. More rugged designs are being prepared.

Summary. To summarize these comparisons, for present usage magnesium would be preferred because of its lower initial cost and because less attention would be required for operation. This is provided, however, that an anode which will last two years will become available. For the future, if a rugged, trouble-free impressed current system with automatic control could be developed that type of system would be preferred.

Future Plans

It would be pleasant to say that the author and his associates are proceeding to outfit the active fleet with cathodic protection. This, however, is not true at present. The hesitation to do this is not caused by any lack of faith in cathodic protection. The reason for the delay is that results are being awaited of current trials with improved magnesium anodes and impressed current systems. As these improve and become less expensive, more and more active ships will be provided with cathodic protection installations.

The opinions or assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

DISCUSSION

Comments by H. S. Preiser, Department of the Navy, Bureau of Ships, Washington, D. C.

Mr. Gessow's excellent presentation has covered the broad aspects of the cathodic protection program in the United States Navy. Certain points mentioned need elaboration for the completion of the record.

Cavitation Damage. A project has been established at the Boston Naval Shipyard for the purpose of determining what portion of cavitation damage can be ascribed to mechanical wear and tear, and what portion to electrochemical attack.

A specially designed cavitating propeller has been built for the test. The blades are insulated from each other and from the drive shaft by a micarta hub. A brush rig has been incorporated into the gear to permit certain blades to be coupled to an external anode system. Weight losses will be made on different blade materials after exposure to cavitating conditions in open sea water. The propeller blades will be coupled cathodically and also run uncoupled. Any observed differences in the weight losses under these conditions will be indicative of the electrochemical component of the total damage which has been suppressed by cathodic protection.

Value of Cathodic Protection. Past experience indicates that the corrosion of propeller shafting could be serious. It must be remembered that in most instances today full reliance is placed on impervious vulcanized rubber shaft and other coatings for corrosion protection. Small perforations in these heavy duty coatings would result in an unfavorable anode (shaft) cathode (propeller) relationship. The pit nucleous thus produced would incite corrosion fatigue and possible failure. Cathodic protection may not eliminate the need for shaft coatings but it is certainly a powerful deterent to corrosion failure should the coating rupture.

Cost of Experimental Cathodic Protection Systems. Some additional installations have been made on fleet type submarines using an all zinc system which included an extensive reference electrode system. The complete cost of this system from design to installation was about $11,000.

Another submarine was outfitted with an aluminum-

[3] Power is always available from the ship's generators, which usually operate below capacity, so power cost is a negligible factor.

zinc alloy cathodic protection system consisting of bilge keel anodes and an extensive anode rod system strung underneath the superstructure and fairwater. The cost including a reference electrode was of the same order as for zinc.

Reserve Fleet. The corrosion attack on ship hulls at fresh water reserve fleet sites is uniform and rather mild. The absence of severe pitting of the hull plates reduces the urgency of protection. But despite the increased difficulty in achieving good current distribution, the surprisingly low cost of installation and maintenance of cathodic protection systems appears to make its use worthwhile.

Magnesium Anode Installations. The unusual consumption of anode material at the fastenings cited in Mr. Gessow's paper probably was due to the exposed metal bus bar connected to the anodes which was grounded internally in the hull through a rheostat. In controlled systems such as these, which use commercial anode shapes, no attempt is made to insulate the bus bar from the sea water. New anode attachment methods are being tried to overcome this difficulty.

Sacrificial Anodes Versus Impressed Current. Although weight is always of concern to the ship operator, it must be considered in relation to other factors. Any extra dead weight results in some loss of cruising range and speed but this usually is negligible when the increase is an infinitesimal fraction of the total displacement.

Geometric factors affecting appendage resistance have greater significance in terms of increased fuel consumption and loss of speed. In the case of a submarine, however, every pound of weight and its location in the ship is important as buoyancy and stability are noticeably affected by relatively small changes.

Durability of Anodes. While it is true that inert sacrificial anodes such as platinum and graphite are relatively permanent, long time performance is dependent on mechanical and material design. Much remains to be done on anode housing materials and methods of construction and fabrication. In addition to this, foolproof electric cable systems for hull penetration also are needed. These aspects of the program are being actively followed up under the Bureau of Ships research and development program on cathodic protection.

Control of Current Output. Dielectric shielding for current control cannot be overemphasized. For magnesium anode systems shields such as 25 mil vinyl paint films appear adequate. The impressed current systems need heavier insulation. One-eighth inch neoprene cold bond sheet patches have performed successfully in service for more than a year. With low voltage systems such as zinc and aluminum-zinc anodes, dielectric shields appear unnecessary on vinyl painted hulls.

General Remarks. Two automatic control systems are under development in the Bureau. One design entails a Servo-controlled rectifier input from an amplified reference electrode potential signal. The other uses a galvanometer sensing unit served by the reference electrode signal, and activates a relay control Servo-mechanism which is geared to regulate the rectifier input.

In closing, I would like to add that the Bureau has been ably supported by the shipyards, laboratories, and fleet personnel in carrying out the minute details that this extensive corrosion control program entails.

Note: The opinions or statements contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

Any discussions of this article not published above will appear in the June, 1956 issue

Dealuminization of Aluminum Bronze*

By MORTIMER SCHUSSLER and D. S. NAPOLITAN

Introduction

A NUMBER OF FACTORS are responsible for the widespread use of aluminum bronzes in industry. Among considerations which may be listed are the high physical strength of such alloys, their resistance to wear and galling, resistance to corrosion and erosion, relative ease of fabrication and low cost. In certain corrosion environments, however, aluminum bronzes can suffer a selective corrosion attack known as dealuminization. This selective attack results in a loss in aluminum from the alloy.

Dealuminization of aluminum bronzes is similar in mechanism to the dezincification corrosion phenomena that occurs on brasses. Only scant data and limited observations on dealuminization have appeared in the literature. Such attack is generally insidious, because it results in a severe loss in strength and ductility of the aluminum bronze and therefore can cause costly and hazardous failures. Failure from dealuminization can occur under unexpected circumstances and with a severity similar to the ruptures resulting from an attack such as that causing stress corrosion cracking. A striking example of a dealuminization failure of a cylinder valve is described below. As a result of that failure, an investigation was made to answer an immediate valve failure problem and, in addition, to determine how to avoid the possibility of similar failures in other applications.

The purpose of this paper is to point out that dealuminization attack on aluminum bronzes can present a failure hazard and that the possibilities for the occurrence of this attack should be recognized. Proper selection of materials, consideration of design, and control of the corrosive environment offer means to avoid failure from dealuminization.

Example of Dealuminization Failure

The "case in point" failure occurred in a union nut on a valve on a cylinder that was used under conditions where aqueous hydrofluoric acid could be formed.

The Failure

The design of the valve, shown in Figure 1, is a two-piece construction in which the bonnet is not integral with the body. The union nut was threaded onto the valve body to effect a metal to metal seal between the valve body and bonnet. The seal was not effective, and aqueous hydrofluoric acid came in contact with the threaded area of the union nut.

The failure occurred as a circumferential splitting of the union nut into two pieces (see Figure 2), with the fracture originating along the periphery of the root diameter of the top thread of the nut. The failure

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Abstract

Though rarer than dezincification in brass, dealuminization can occur in aluminum bronze, and such attack can constitute a failure hazard. A case of a dealuminization failure in a cylinder valve is cited. This failure was attributable to selective corrosion of the aluminum-rich phase in an aluminum silicon bronze having a duplex structure.

In the process of selecting a more suitable material for the cylinder valves, dealuminization studies were carried out on samples of single and two phase aluminum bronzes which were exposed to aqueous hydrofluoric acid, the corrosive agent to which the valve failures were affixed. Alpha aluminum bronze suffered no harmful attack; the duplex aluminum bronze, regardless of its heat treated structure, suffered a selective dealuminization attack which caused a severe loss in ductility.

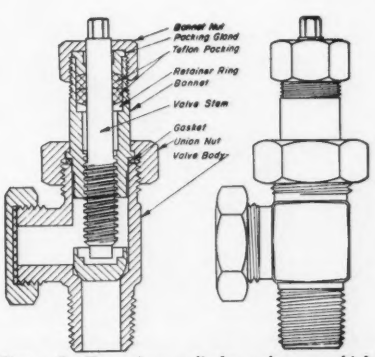

Figure 1—Two piece cylinder valve on which a union nut failure occurred. ⅓X.

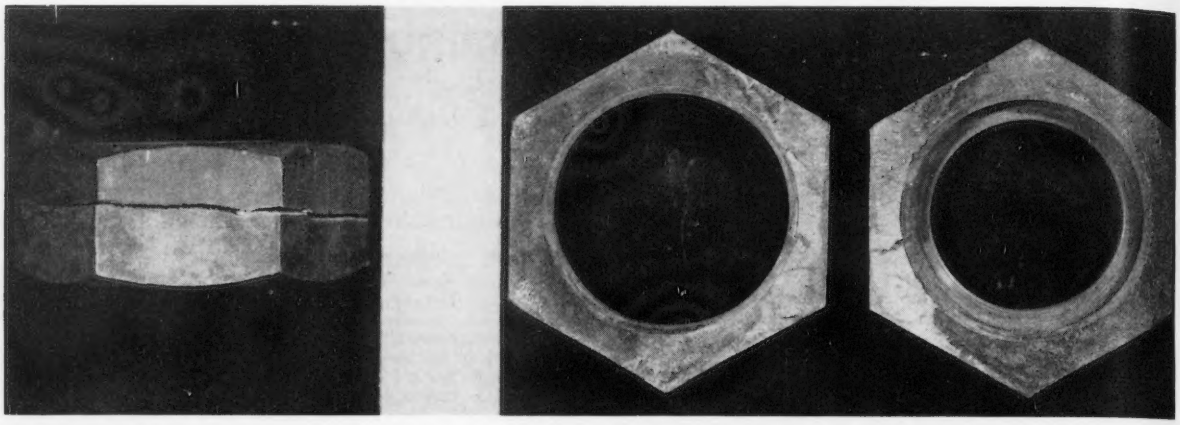

Figure 2—Two views of failed union nut. At left is side view and at right is fracture surface. 1X.

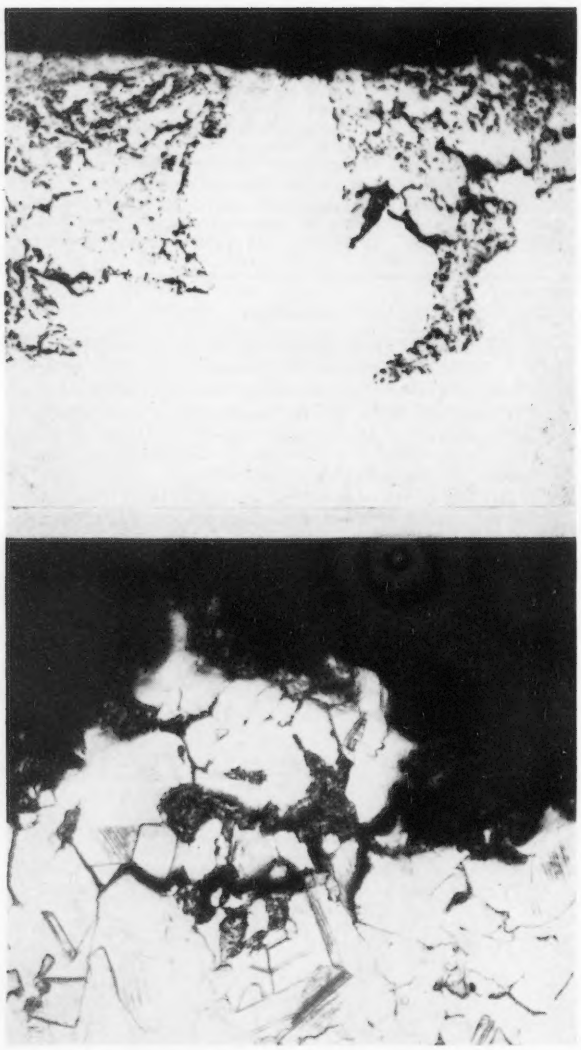

Figure 3—Cross section of failed union nut along fracture showing dealuminization attack in the aluminum-rich, second phase in the structure. Sample at top is unetched and at bottom is etched. 555X.

of the nut resulted in the bonnet assembly being thrown off the valve with explosive force. There was a subsequent loss of the cylinder contents.

Characteristics of the Failure

The material in the failed union nut was identified as an aluminum-silicon bronze which analyzed 9.7 percent aluminum, 1.6 percent silicon, 0.06 percent manganese, and the balance was copper; it had a hardness of Rockwell B 92.

The fracture surfaces on the failed union nut (Figure 2) showed most of the surface to be tarnished as if the fracture had existed for some time. The area of final fracture at the time of failure, however, appeared bright.

The microstructure of the material showed a two phase structure; i.e., copper rich grains comprising the majority and aluminum rich grains the minority of the structure. In the tarnished area of the original fracture, the aluminum rich phase had been attacked selectively by aqueous hydrofluoric acid.

Figure 3 shows the nature of the chemical attack on a sample in both the unetched and etched conditions. The attack apparently had dissolved the aluminum-rich phase, and copper replated from the corrosive agent. This chemical attack severely weakened the structure and, when high torque was applied to the nut, a crack developed at the root of the top thread. Corrosion and further cracking in combination propagated the failure. The final fracture was completed by additional torque loading, applied to the union nut in an effort to stop the leak.

Aluminum silicon bronze nuts which had not failed in the same service showed signs of dealuminization attack, but to a much less extent than was observed on the failed nut. A few of these aluminum silicon bronze union nuts showed some cracking at the root of the upper thread.

The visual evidence of dealuminization is much more striking than illustrated in this paper. When examined with the unaided eye, aluminum bronze that is dealuminized appears to be copper plated. A metallographic examination is required to determine whether such attack has been of a general and slight, relatively innocuous nature, or whether it has been

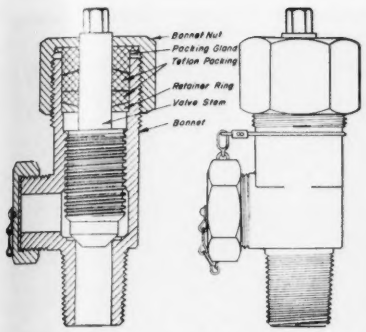

Figure 4—One piece cylinder valve used for replacement of the two piece valve. ⅓X.

severe, selective and highly destructive. Examination of the structure shown in Figure 3 under polarized light without filters showed the copper residue standing out clearly in brilliant crimson (in contrast to the dark appearance of the unaffected structure).

Remedial Action

As an immediate action to minimize the possibility of failures from dealuminization of the two piece valves, the aluminum silicon bronze union nuts were replaced with electroless nickel coated steel nuts. A 1/32 inch thick Fluorothene gasket and a 7 degree taper on the valve body gasket surface were used to effect a leak-tight seal between the valve body and the union nut. The torque applied to the union nut to affect this seal was limited to 150 foot-pounds maximum.

Subsequently, the two piece valves in this service were replaced with valves of improved design (Figure 4) and materials. The redesign of the bonnet as outlined in Reference 1 eliminated failures from stress corrosion cracking. The one piece construction obviated the union nut problem, and the use of an alpha (single phase) aluminum bronze disposed of the possibility of dealuminization failures. The selection of an alpha aluminum bronze for the valve body was made on the basis of the dealuminization study which is discussed below.

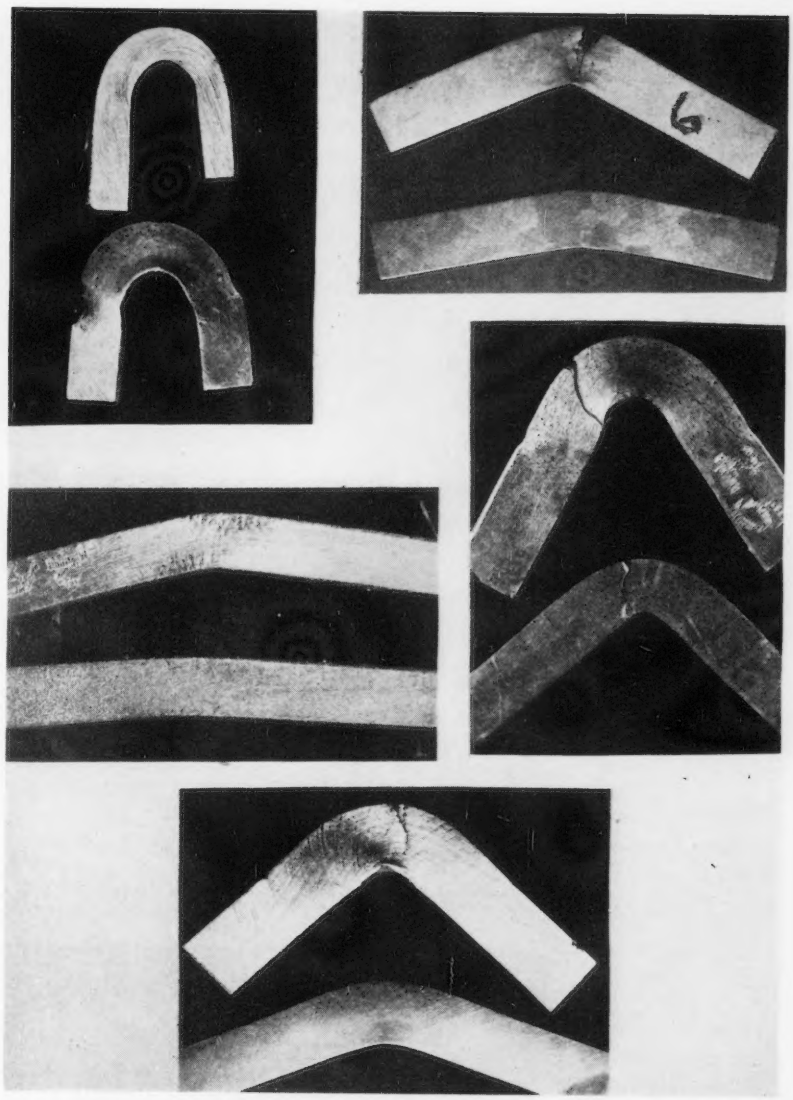

Figure 5—Bend test specimens of unexposed (top in each photograph) sample and of exposed (bottom in each photograph) sample of duplex aluminum bronze with indicated structure. Top row, left to right: alpha structure, kappa structure; middle row, left to right: alpha plus kappa structure (Method 1), alpha plus kappa structure (Method 2); bottom row: alpha plus eutectoid structure. 2¼X.

Dealuminization Study on Aluminum Bronze

Very little information on dealuminization could be found in the literature but it was determined that the process of dealuminization is generally considered to consist of dissolution of the metal as an alloy and subsequent replating of copper from the solution. The mechanism of dealuminization may require the presence of an aqueous solution or electrolyte in which aluminum is more soluble than is copper. With regard to the observations on the service conditions of the union nuts, aqueous hydrofluoric acid was suspected as the corrosion agent which could produce the observed effects.

Materials Tested

Dealuminization studies were conducted by immersing the aluminum bronze samples in aqueous 48 percent hydrofluoric acid at 150 F. The materials investigated were a single phase (alpha) and a two phase (duplex) aluminum bronze. The alpha single phase material was in the form of a round bar and had a composition of 4.38 percent aluminum, 0.38 percent iron, 1.10 percent silicon, and the balance copper.

The material having two phase structure was in the form of forged stock and conformed to Federal Specification QQB-666, Grade B, having a composi-

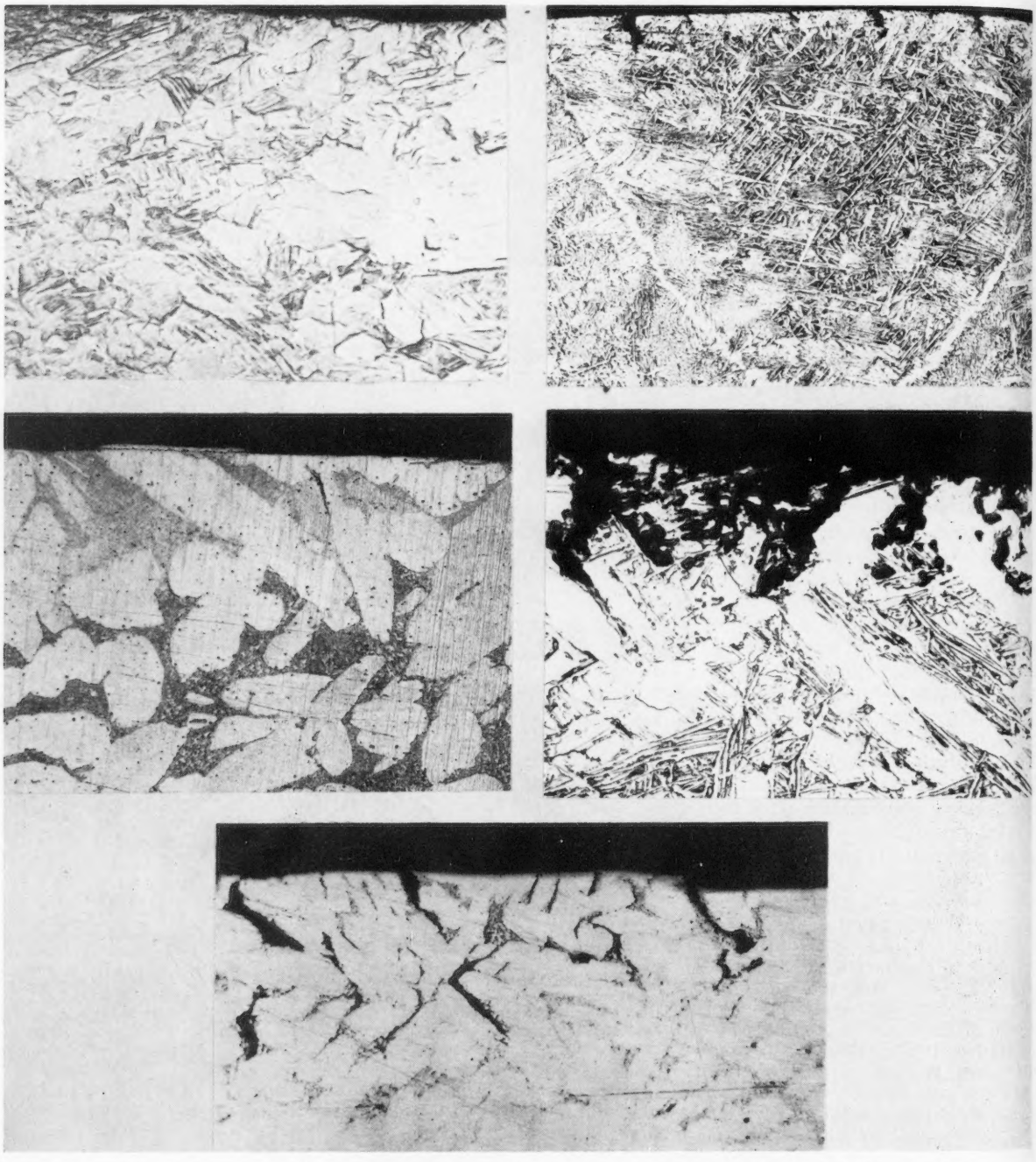

Figure 6—Cross sections of exposed samples at outer surface at position of maximum bend to show depth of dealuminization attack on each structure produced in a duplex aluminum bronze. Top row, left to right alpha structure (575X), kappa structure (87X); middle row: alpha plus kappa structure (Method 1, 87X), alpha plus kappa structure (Method 2, 575X); bottom row; alpha plus eutectoid structure (164X).

tion of 9.0 percent aluminum, 1.7 percent iron, and the balance copper. These materials were selected because of their particular suitability to the fabrication methods for cylinder valves, which require a material of adequate mechanical properties that can be readily forged and machined.

Preparation of Samples

The test specimens were prepared in the form of strips ¼ inch x ¼ inch x 1 inch and were taken in a longitudinal direction from the stock. The samples of the alpha (single phase) structure were tested in the "as supplied" condition.

Heat-treatments of the two phase material were conducted to obtain altered structures of this material. The heat-treatments were designed to produce samples of a kappa (quenched beta) structure and of an alpha plus kappa structure. The kappa structure was obtained by heating the specimens to a temperature of 1750 F which transformed the

material to the beta phase. Following a soaking treatment at temperature, the samples were water quenched to obtain the kappa phase, which had an acicular structure very similar to martensite in steel. The structure also indicated the tendency for excessive grain growth of the beta phase during this high temperature treatment.

The alpha plus kappa structures were obtained in other samples by two different methods of heat-treatment of the forged "duplex" aluminum bronze. The first method was to heat-treat specimens for two hours at a temperature of 1750 F to produce a beta structure. These specimens were then allowed to cool in the furnace to 1110 F and were maintained at this temperature for 24 hours, then quenched in water. This treatment resulted in a coarse grain, beta phase, which on subsequent slow cooling to a temperature of 1110 F was partially transformed into kappa phase along with large slabs of alpha phase.

The second method used to produce an alpha plus kappa structure was to heat the specimens to 1750 F for a short (five minute) soak to obtain a beta structure, followed by a water quench to obtain a kappa structure. To obtain alpha plus kappa from this kappa structure, a temperature in excess of the transformation temperature for the eutectoid was chosen (1110 F) for reheating. The transformation time at 1110 F was 24 hours. Following this treatment, the samples were quenched in water. The structure produced by the double quenching technique showed the alpha phase transformed from a quenched beta structure, yielding the desired, fine grained, alpha plus kappa structure. In developing this heat-treatment it was found that the relative amounts of alpha and kappa that resulted were dependent on both the temperature and time at temperature of the treatment.

In addition to these induced structures, samples of the alpha plus eutectoid structure that existed in the as forged stock were included in the corrosion tests.

Test Procedure

One series of samples was exposed totally immersed in aqueous 48 percent hydrofluoric acid contained in a Fluorothene beaker at a test temperature of 150 F for a 72 hour period. A second series of samples, not exposed to the hydrofluoric acid, was retained for control purposes. The structures represented in both series were alpha, kappa, alpha plus kappa (produced by the two different treatments cited), and alpha plus eutectoid.

The extent of the corrosive effect of the hydrofluoric acid on the respective structures of the exposed samples was evaluated by microstructure examination and by bend tests. The bend tests were utilized to determine the ductility of the specimens in the "as received" and "as altered" structure conditions, and after exposure to hydrogen fluoride. The degree of bend required to produce visible cracks or failure was used to evaluate the ductility of the structures before and after exposure to the corrosive agent.

It should be noted that the initial ductility before exposure to the corrosion test varied considerably between the materials with the various microstructures. The ductility was low in the kappa structure, and in the alpha plus kappa structure which was produced by slow cooling from the single phase beta zone. The tempered structure of alpha plus kappa yielded a material slightly more ductile than the "as forged," alpha plus eutectoid structure. In the alpha plus kappa structure obtained by double quenching, the kappa phase imparted strength and the alpha phase the ductility. The alpha material successfully withstood a 180 degree bend.

Results of Tests

The observations from these tests are presented pictorially in Figures 5 and 6. The bend test specimens representing each heat-treated structure are shown in Figure 5. In each individual photograph, the unexposed sample is shown at the top and the exposed sample is shown at the bottom.

The appearance of the samples as illustrated would suggest that the unexposed samples had been bent to complete failure, while in most cases the exposed samples had been stopped as soon as surface cracking became apparent. This resulted because of the manner in which the samples cracked. The exposed samples that experienced dealuminization attack cracked with slight bending through the dealuminized layer, then the cracking stopped when the higher ductility, unaffected base metal was reached.

On the other hand, the unexposed samples of susceptible structures underwent a greater bend before any cracking occurred, but the initiation of cracking resulted in immediate, nearly complete failure of the samples.

The depth of dealuminization attack that produced the loss in ductility of susceptible materials is shown in Figure 6. These photomicrographs of the outer surface of cross sections were taken at the position of maximum bend on the exposed samples.

The alpha structure, which did not show any loss in ductility as a result of exposure to aqueous hydrofluoric acid, had no evidence of selective corrosion. The kappa structure suffered an attack to 0.004 inch depth. The alpha plus kappa structures were attacked to depths of 0.014 inch and 0.002 inch, respectively as heat treated by methods 1 and 2. The alpha plus eutectoid structure was attacked to a depth of about 0.010 inch. The affected area in the alpha plus kappa structure produced by slow cooling from the beta range, and the alpha plus eutectoid structure also show distinct color differences in the aluminum rich phase between the affected surface layer and the unaffected, underlying material.

Conclusions

Only an alpha aluminum bronze is resistant to environments that can produce a dealuminization attack on aluminum bronzes. Apparently, a duplex aluminum bronze of the type tested is not made resistant to such an attack by altering its structure, and suffers a serious loss in strength and ductility as a result of the attack.

Failures of serious consequences can result from dealuminization under expected circumstances, as evidenced by a cylinder valve failure. The possibility that aluminum bronzes can suffer this destructive form of corrosion should be given attention in the selection of materials for handling aqueous solutions or vapors of corrosive chemicals.

Acknowledgment

This paper is based on work performed for the Atomic Energy Commission by Union Carbide Nuclear Company, at Oak Ridge, Tenn.

Reference

1. Mortimer Schussler. Minimizing Stress Corrosion Cracking of Cylinder Valves, *Corrosion*, **11**, No. 3, 105-108 (1955).

Any discussions of this article not published above will appear in the June, 1956 issue

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The Role of Nickel and Nickel Substitutes In Jewelry Making*

By K. H. MAIRS and J. M. WILLIAMS

Introduction

NICKEL HAS BECOME an important material in the manufacture of low and medium priced jewelry. Wrought low-carbon nickel is widely used in the production of gold-filled and rolled gold plate both as the base metal itself and as an interliner.

Articles of jewelry finished by electroplating almost always have an undercoat or interliner of bright nickel electrodeposit. Nickel also is important as an alloying substance; many gold alloys contain nickel as a hardener and grain refiner. In the white golds, nickel is the principal color controlling agent.

Many articles of jewelry combine the precious metal products mentioned above with other structural parts in which nickel plays an equally important role. For example, an expansion watch bracelet may have gold-filled-on-nickel top shells over a skeleton of pure nickel while the back shells are made from chromium-nickel austenitic stainless steel. The coiled springs which give the bracelet ability to contract and fit snugly to the wrist are usually made from Type 302 chromium-nickel stainless steel.

Figure 1 shows a partially disassembled watch bracelet with the component parts identified. The popularity of nickel for a product such as watch bracelets is derived from the metal's excellent forming characteristics, its generally good corrosion resistance, and its pleasing color and good strength.

Nickel Substitutes

In times of national emergency the use of nickel in jewelry making has been drastically curtailed. During the Korean War, for example, National Production Authority Order M-80 virtually eliminated the use of nickel and nickel-containing materials; only functional springs could be made of austenitic stainless steel, and certain rivets and eyelets could be made of nickel silver. The use of nickel as an electrodeposited undercoat, and as an interliner in wrought products was the subject of much debate. Use of this material finally was permitted, however, with various restrictions. The manufacture of white golds containing more than 7 percent nickel was prohibited. Obviously, under such conditions, there was a tremendous demand for nickel substitutes, particularly for the manufacture of gold-filled and rolled gold plate and for the complimentary structural parts.

Shortly after the beginning of the Korean War, Type 430 stainless iron was offered as a substitute for both nickel and austenitic stainless steel. This material was used rather extensively by jewelry manufacturers, but its corrosion resistance was not

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Abstract

Numerous laboratory tests are reported of couples between 24 and 10 karat gold, sterling silver, 800 silver, 430 stainless iron, composition, 10 percent nickel silver, 18 percent nickel silver, aluminum bronze, LC nickel and 305 stainless steel in both acid and alkaline synthetic perspiration. Expected potential difference occurred between the materials and gold. Type 305 stainless steel showed the least tendency to corrode with the copper base alloys showing the greatest tendency toward corrosion. Potentials in acid perspiration were greater than those in alkaline.

The authors conclude alloys which develop protective films are more satisfactory than those which do not. Resistance of nickel is not entirely satisfactory but no single substitute has the general usefulness of nickel. Under many conditions Type 430 stainless iron is not sufficiently resistant to be useful in jewelry making.

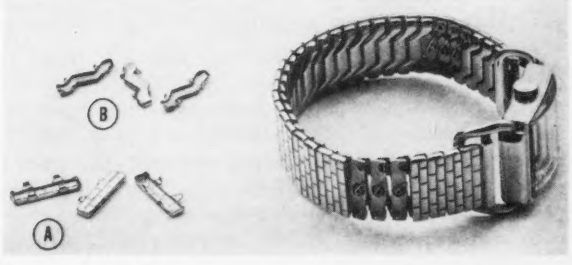

Figure 1—A partially disassembled watch bracelet. Topshells (A) and backshells (B) cover the outer and inner surfaces of the skeleton respectively. A coiled spring in each link keeps the bacelet normally closed.

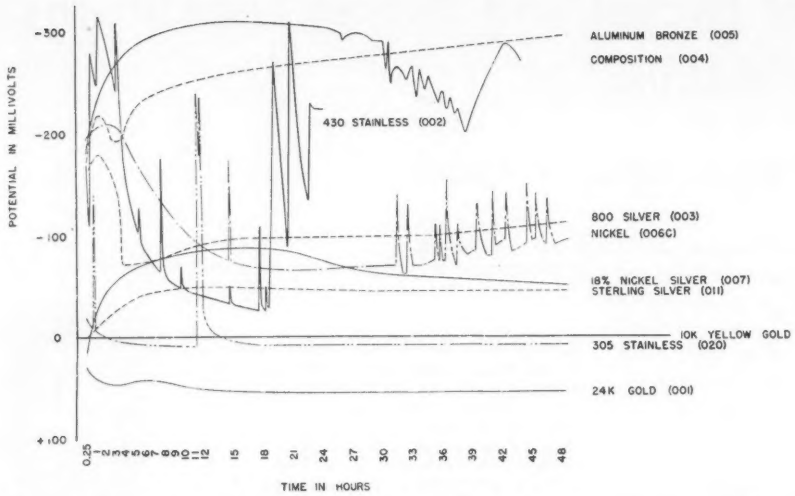

Figure 2—Open circuit potentials for 10 karat gold alloy versus various annealed materials in alkaline synthetic perspiration.

TABLE 1—Composition of Materials Used in Open Circuit Potential Tests

MATERIAL	COMPOSITION
24 Karat Gold	99.95% Au, min.
10 Karat Yellow Gold	41.67% Au, 38.5% Cu, 5.83% Ag, 12.83% Zn, 1.17% Ni
Sterling Silver	92.5% Ag, 7.5% Cu
800 Silver	80% Ag, 20% Cu
430 Stainless Chrome Iron	
Composition[1]	92% Cu, 7% Zn, 1% Sn
10% Nickel Silver[2]	66.7% Cu, 9.3% Ni, 0.05% Pb max., 0.05% Fe max., 0.50% Mn max., bal. Zn
18% Nickel Silver[2]	65.4% Cu, 18.7% Ni, 0.10% Pb max., 0.25% Fe max., bal. Zn
Aluminum Bronze	92% Cu, 8% Al
LC Nickel	0.02% C, max.
305 Stainless Steel	

[1] A copper base alloy widely used throughout the jewelry industry as a base for rolled gold plate.
[2] The open circuit potential patterns of 10 and 18 percent nickel silvers are so similar there is not sufficient reason to consider each material separately. Comments concerning one material apply equally well to the other.

satisfactory and it was not widely accepted. By late 1952 it was evident that the general quality of watchbands had fallen noticeably and that the percentage of bands damaged and destroyed by corrosion was increasing alarmingly. It was decided at that time to determine the role nickel played in making quality jewelry, and to outline the characteristics that were required in acceptable substitutes.

Inasmuch as corrosion was responsible for most of the obvious damage, a series of observations was made of the open circuit potentials developed between a typical 10 karat yellow gold alloy and the materials with which it might ordinarily be paired. Potential differences were recorded on a high impedance recording potentiometer for periods of approximately 48 hours. The recorder was an emf actuated Foxboro Dynalog modified to give a scale range of ± 300 millivolts. When potentials exceeded 300 millivolts, a suitable back emf was impressed to keep the record on scale.

Each pair of materials was tested in two different electrolytes (in an alkaline, and in an acid synthetic perspiration prepared in accordance with the recommendations of ASTM Specification D627-49T.[1])

Synthetic Perspiration Solutions

The composition of synthetic perspiration solutions was as follows:

Alkaline Solution[2]

10 grams sodium chloride
4 grams USP ammonium carbonate
1 gram disodium orthophosphate

Acid Solution[2]

10 grams sodium chloride
1 gram lactic acid
1 gram disodium orthophosphate

Each material was tested in two physical conditions (annealed, and cold rolled to 50 percent of the original thickness.) The test cells were run at room temperature and recorded at 75-80 F.

The several materials included in this test program are listed in Table 1. Materials 3 to 10 are those usually combined with a gold alloy, such as material 2, to produce the precious metal bimetals. To be marked gold-filled, the bimetal must have a gold alloy layer of at least 10 karat quality which accounts for 5 percent or more of the weight of the composite. Bimetals having less than 5 percent of gold alloy are known as rolled gold plate.

Because of its high cost, 24 karat gold does not play an important part in low and medium priced jewelry. It is included here only as a reference material. Type 305 stainless steel is included because of its importance as a structural material. Because of its high annealing temperature, this type stainless steel is not suitable as a base for gold-filled and rolled gold plate.

Several of the materials included in Table 1 are used also for the manufacture of structural parts. Nickel may be considered the most generally satisfactory material for watch band skeletons, but other materials, particularly 18 percent nickel silver and Type 305 stainless steel, have been used successfully. The unrestricted use of these nickel-containing materials was prohibited by Order M-80. As a result, skeletons were made of 430 stainless iron, composition, 10 percent nickel silver, and combinations thereof. Whenever two or more distinctly different materials were employed, corrosion became a serious problem.

A few experimental bracelets were made with

[1] The same synthetic perspirations are described by Federal Spec. CCC-T-191b (method 5682).
[2] Dissolved in distilled water and diluted to 1 liter.

skeletons of sterling silver but, as was anticipated, they exhibited poor strength and wear characteristics. In addition, sterling silver was observed to tarnish and corrode severely. The products of corrosion spread over the gold surface, resulting in discoloration of wrist and apparel of the wearer.

The back shells of quality watch bracelets have traditionally been made of Type 305 stainless steel. During the Korean war, this part was made satisfactorily from 430 stainless iron. Reasons for the success of this substitution are as follows:

1. The part is simple to form.
2. The part gets a good mechanical polish.
3. The part receives mild frictional wear which prevents pitting despite the presence of body perspiration.

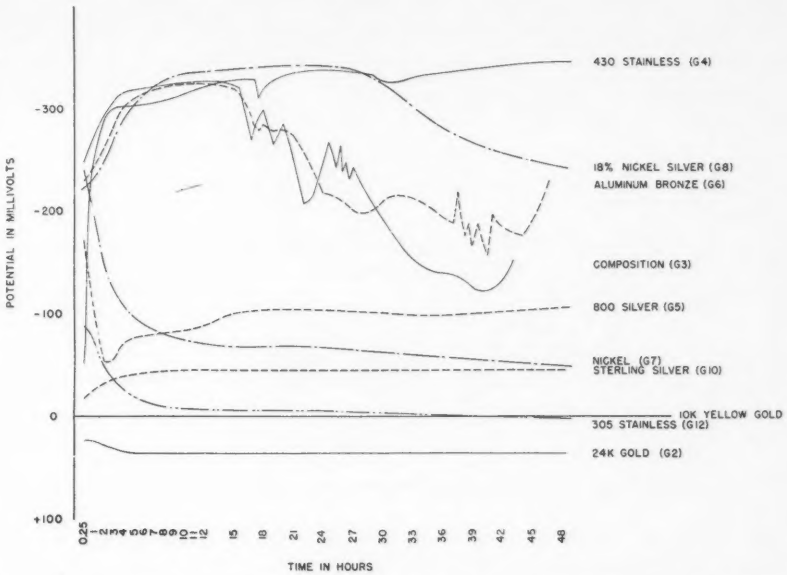

Figure 3—Open circuit potentials for 10 karat gold alloy versus various 50 percent cold rolled materials in alkaline synthetic perspiration.

Results

The results of the numerous open circuit potential tests can best be appreciated by referring to Figures 2 to 5, where the materials are grouped according to physical condition and kind of electrolyte employed. All materials above the 10 karat gold reference are anodic to this alloy, and would corrode under certain conditions if the two came in metal-to-metal contact. The greater the potential difference, the greater is the driving force to initiate corrosion.

Annealed Materials in Alkaline Solution

Figure 2 for annealed materials in alkaline synthetic perspiration shows these interesting facts:

1. As might be expected, the 10 karat gold alloy is anodic to (less corrosion resistant) 24 karat gold. After approximately 15 hours, a constant potential difference of 54 millivolts was observed.

2. Type 305 stainless steel is "more noble" than this particular 10 karat yellow gold. However, the potential difference is very small, and there is essentially no tendency for the gold alloy to corrode or deteriorate. The breaks in the curve at approximately 1 and 11 hours indicated temporary lack of passivity or stainlessness. Re-establishment of the stainless properties occurred with the healing of the protective film.

3. During the first 18 hours, 430 stainless iron tended to become passive, and to develop a reasonably small potential. Normal corrosion, however, destroyed the protective oxide film and the material thereafter was no longer stainless.

4. Nickel, the nickel silvers, and sterling silver were anodic to this 10 karat gold alloy, and developed approximately the same tendencies to corrode. The magnitude of these potentials is not considered objectionable. It is the authors' experience that potentials of less than about 100 millivolts do not develop objectionable corrosion during the ordinary service life of this type of jewelry. Potentials of 100 to 200 millivolts can, and do, promote objectionable corrosion; potentials of more than 200 millivolts are very objectionable.

The curve for nickel is fundamentally different from the curves for the nickel silvers and sterling silver. After reaching a minimum at about 21 hours, the nickel curve developed irregularities typical of materials protected by passive films. The curves for nickel silver and sterling were smooth and regular.

5. The open circuit potential for 800 silver was twice as large as that for sterling silver. After 35 hours, the potential of 800 silver began to increase slowly with time (due possibly to the marked tendency of copper to go into solution).

6. The copper base alloys, composition, and aluminum bronze, developed large potentials, and were, therefore, the least satisfactory. The erratic behavior of composition after 39 hours undoubtedly is related to extensive solution of copper into the electrolyte.

Cold Rolled Materials in Alkaline Solution

By the time these various materials have been fabricated into component parts, they may have experienced a considerable amount of cold working. Figure 3, when compared with Figure 2, shows the influence of 50 percent cold work by rolling. The comparison may be summarized as follows:

1. The potential of 10 karat yellow gold with respect to the 24 karat gold reference was, for all practical purposes, unaffected by this degree of cold working. The same may be said for the relative potentials of sterling, 800 silver, and nickel.

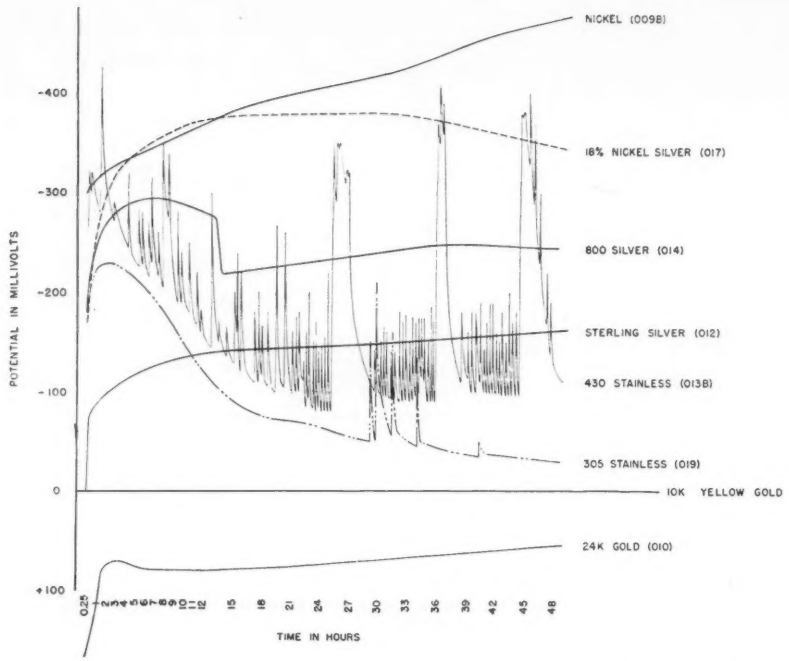

Figure 4—Open circuit potentials for 10 karat gold alloy versus various annealed materials in acid synthetic perspiration.

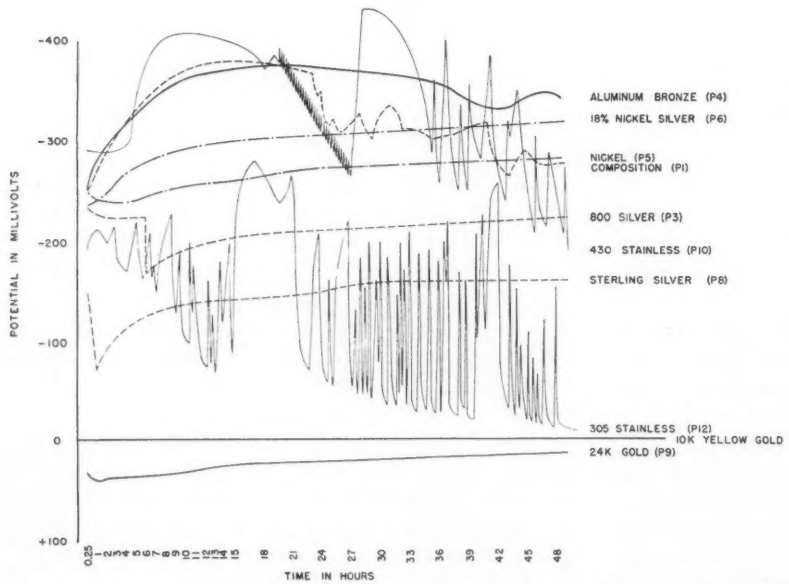

Figure 5—Open circuit potentials for 10 karat gold alloy versus various 50 percent cold rolled materials in acid synthetic perspiration.

2. The magnitude of the open-circuit potentials for composition and aluminum bronze was increased slightly and the interval of time required to reach maximum was shortened (especially in the case of aluminum bronze). Both readings became erratic after approximately 15 hours, and both materials showed marked solution of copper into the electrolyte.

3. The open circuit potentials for nickel silver were vastly increased by cold working. It must be noted that these materials show very satisfactory tendency to resist corrosion when annealed, but fabricating operations change this quality adversely.

4. Type 430 stainless iron developed a very unfavorable corrosion tendency as the result of cold working. This particular electrode actually was not stainless (a scab of red iron rust formed during the test).

Annealed Materials in Acid Solution

Figure 4 expresses the behavior of annealed materials in acid synthetic perspiration. In this connection the following things were found:

1. The magnitude of all open-circuit potentials was greater in acid than in alkaline synthetic perspiration.

2. The potential difference between 10 karat yellow gold and 24 karat gold reference diminished constantly over a 72 hour test period. There is reason to believe this is the result of the acid environment reacting with zinc in the gold alloy. It was impractical to continue tests in acid environment beyond this interval because of bacterial growth in the electrolyte.

3. Of the several materials tested, 305 stainless steel showed the least tendency to corrode. In Figure 4, only the minimum of the potential trend is shown during the first 24 hours. Actually, there were 24 pronounced pips during this time, but they are not shown because they are difficult to distinguish from the curve for 430 stainless iron. The curve for the second 24 hours is reproduced faithfully; only 5 pips were recorded as shown. The test was continued for an additional 18 hours and, during this extra interval, only 2 pips were observed.

4. The curve for 430 stainless iron is most interesting. It represents a material fluctuating rapidly between active and passive conditions. Local corrosion was trying to establish a protective film but the film was not adequate in that environment.

5. Both silver base materials had appreciably greater tendency to corrode in acid environment. While these materials show an increasing emf with respect to 10 karat yellow gold, they show practically a constant emf with respect to 24 karat gold.

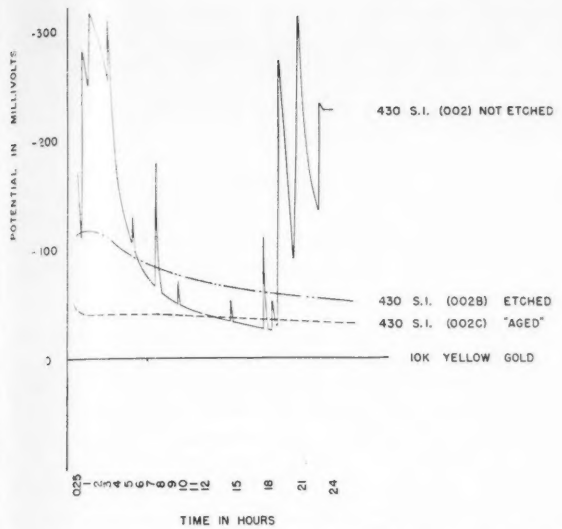

Figure 6—Open circuit potentials for 10 karat gold alloy versus annealed 430 stainless iron with various initial surface conditions.

6. Composition, aluminum bronze, and the nickel silvers showed almost identical open circuit potential patterns; all were severely attacked by local corrosion during their tests.

7. Nickel showed a maximum tendency to corrode in this acid environment. Fortunately, attack under these conditions was uniform, and there was little tendency toward pitting or crevice corrosion.

Cold Rolled Materials in Acid Solution

Figure 5 shows the behavior of the 50 percent cold worked materials in acid synthetic perspiration. Comparing Figures 5 and 4 the following observations can be made:

1. The potential difference between the 10 karat gold alloy and 24 karat gold diminished at approximately the same rate as did the materials in the annealed condition. The somewhat greater potentials for the 10 karat alloy in the annealed condition may be related to the adsorption of extra zinc onto the surface during the annealing operation.

2. The combination of acid environment, plus cold rolling, was sufficient to make 305 stainless steel fluctuate between active and passive condition. It should be noted, however, that performance improved with time; the potential difference, after 48 hours, was reasonably small.

3. The open circuit potential pattern for sterling silver was practically unaffected by 50 percent cold working, and 800 silver was modified but slightly. It is obvious that these silver base materials are influenced primarily by their environment, and to a smaller extent by cold working.

4. The curves for nickel and 18 percent nickel silver are essentially parallel to the curve for 24 karat gold, but with larger potential differences. Both materials, and particularly nickel, showed a better behavior in the cold worked condition than in the annealed condition. The reason for this has not yet been established, but it may be related to surface contamination during annealing.

5. The curves for composition and aluminum bronze are essentially the same whether cold rolled or annealed. These materials were influenced more by the variety of electrolyte employed than by cold rolling.

6. Type 430 stainless iron had a very unfavorable potential pattern under these test conditions.

Discussion

One striking feature of these families of curves is the irregular versus the smooth curve. The sharply irregular curves are characteristic of those materials which possess corrosion resistance because of protective surface films. The smooth curves generally belong to those materials which do not develop such films.

Noncorrosive characteristics of stainless steel are related to the stability of surface oxide film toward any particular environment. Any condition which destroys or removes the protective film adversely affects its stainless qualities. Type 305 stainless steel was completely satisfactory in alkaline perspiration and was generally satisfactory in acid perspiration. The protection which was provided by the surface films was not modified greatly by cold work in either environment.

The natural oxide film over 430 stainless iron was not extensive enough to protect this material from the perspirations in which it was immersed. The initial behavior of annealed material in alkaline perspiration seemed satisfactory, but continued exposure, influence of mechanical working, and the change to an acid environment, all detracted from its stainlessness.

The influence of surface film condition on 430 stainless iron is further illustrated by Figure 6. Curve 002 was "as received" material from which the electrode had just been sheared. The initial potential of more than 300 millivolts reflects corrosion attack at the unprotected edges whereas the decrease to approximately 30 millivolts reflects local corrosion developing temporary protection. Subsequent irregularities indicate general lack of stainlessness.

Curve 002 B is for an electrode sheared from the same coil, but etched in hot chromic acid-hydrofluoric acid prior to test. Curve 002 C is for an electrode sheared from the same coil of material, but not tested until 71 days after shearing. The opportunity to form a protective film from either natural or artificial means improved the corrosion resistance of this material.

Nickel develops a protective film in alkaline perspiration but is rather seriously attacked by acid perspiration as indicated in Figures 2 and 4 respectively. The surprisingly high initial potential of nickel in alkaline solutions (Figures 2 and 3) can be explained by the presence of a small quantity of zinc on the nickel surface. This material undoubtedly was introduced when nickel was being annealed in a furnace previously used for processing brass and other

zinc containing alloys. When nickel electrodes were cleaned by chemical etching, the large initial emf was not observed.

None of the curves represents actual galvanic corrosion. Each curve shows simply the tendency for a pair of materials to react with an environment of synthetic perspiration. Those materials which formed protective films showed little potential difference from the gold alloy. Therefore they would provide driving forces insufficient to initiate and sustain galvanic corrosion. The copper base alloys, such as the composition and aluminum bronze, do not develop protective films. Consequently, there can be pronounced corrosion with the formation of blue-green copper salts.

The silver base alloys, sterling and 800 silver, are materials of intermediate corrosion resistance. The copper-rich phase of these alloys is considerably less corrosion-resistant than the silver-rich phase. Local corrosion of the 800 silver was quite pronounced, with appreciable copper going into solution in the electrolyte and with a roughening of the electrode surface.

Conclusions

In connection with this study the following conclusions can be made:

1. The resistance of nickel to corrosion by synthetic perspirations is not completely satisfactory. In acid perspiration there can be marked general attack on this metal, but, fortunately, there is little tendency toward pitting or crevice corrosion. It is fortunate also that the normal products of corrosion are neither voluminous nor highly colored. For these reasons it is possible for articles made of nickel to withstand considerable corrosion without harmful or objectionable results.

2. No single substitute material has been recognized that possesses the general usefulness of nickel for jewelry making.

3. Type 305 stainless steel has excellent general characteristics, but, because of its high annealing temperature, it is not a suitable base for gold clad materials. Type 305 stainless steel is a most satisfactory structural material and without doubt represents the most economic use of the metal nickel.

4. Under many conditions, Type 430 stainless iron is not sufficiently resistant to corrosion by perspirations to be of great value in jewelry making. There are a few exceptions to this statement, and it is quite possible that the development of better passivation treatments would make this material of more general value. Type 430 stainless iron appears to be especially sensitive to crevice type corrosion.

5. The copper base materials including 10 percent and 18 percent nickel silvers have generally poor corrosion resistance to perspirations. All of these materials yield highly colored and objectionable copper corrosion products. The coupling of most copper base alloy with Type 430 stainless iron greatly accelerates the corrosion of the latter material. Metallic copper deposited on the steel surface by chemical replacement develops local corrosion cells.

6. The silver base alloys, and especially sterling silver, have reasonably good corrosion resistance toward perspirations. They are not acceptable substitutes for nickel in jewelry making, however, because of their: (1) Lack of strength, hardness and wear resistance, (2) Considerably higher cost, (3) Tendency to tarnish and corrode easily from agents other than perspirations, (4) Softness and lack of compressive strength at the temperatures required for cladding.

7. Of all of the materials tested, nickel has the best combination of properties for use as the base of rolled gold plate.

Acknowledgment

This article is based in part on studies made for the New England Manufacturing Jewelers' and Silversmiths' Association by the Engineering Experiment Station, University of Rhode Island, and by Metals & Controls Corporation of Attleboro, Massachusetts.

Any discussions of this article not published above will appear in the June, 1956 issue

Positive-Polarity Grounding of Direct Current Supply Requirements In Mining Traction Systems*

By SIDNEY A. GIBSON

Introduction

IN APRIL, 1949, Subcommittee TP-12 on Electrical Grounding Practices was appointed by the NACE to discuss corrosion problems arising from the positive-polarity grounding of DC supply equipment and to make recommendations on this subject.

The following recommendations were made:[1]

1. Negative-polarity grounding of DC traction power supply equipment is preferable from the standpoint of the stray current electrolysis problem of underground structures.
2. New installations of DC power supply equipment should be grounded on the negative side.
3. Every consideration should be given to converting existing positive-polarity grounded systems to the conventional negative ground.

The fact that the above association recognized the corrosion aspects of this problem and took action is indeed commendable. However, the problems relative to positive-polarity grounding of DC supply equipment in the mining industry are even more serious than was first apparent. The author's experiences indicate that this problem encompasses not only the corrosion of underground metallic structures but also two additional problems of an even more serious nature. These problems are: (1) Abnormally increased maintenance costs due to excessive trolley insulator failures, and (2) Potentially hazardous conditions brought about by the possible formation of metallic sodium or potassium in elemental and very reactive states.

It is the purpose of this paper to describe some of the actual experiences with positive-polarity grounding in the company's Mining Division and to show why the only two of the company's mines using this system were converted. An important reason for making this information available to others in the mining industry is the recent report that there were

*Submitted for publication November 12, 1953. A paper presented at the Tenth Annual Conference, National Association of Corrosion Engineers, Kansas City, Missouri, March 15-19, 1954.

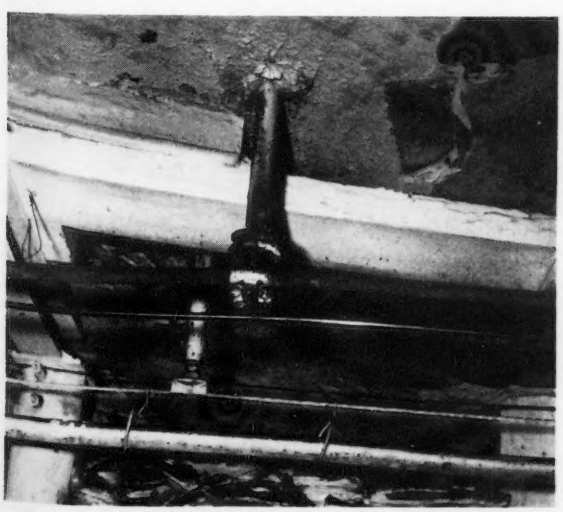

Figure 1—Typical installation of insulated trolley support in mine.

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Abstract

Serious corrosion of mine traction systems using positive-polarity grounding of direct current supply equipment is described. Abnormally increased costs from excessive trolley insulator failures and a safety hazard resulting from possible formation of pure metallic sodium or potassium in corrosion products are reported.

As a consequence of these conditions, Tennessee Coal and Iron Division of U. S. Steel Corporation has converted the only two of its mines in which the traction systems were designed for positive-polarity grounding of negative-polarity trolleys.

Reasons for the installation in mines of positive-polarity systems are given. Illustrations show how the corrosive electrolysis destroys the rock in which trolley supports are fastened.

Tests indicate the presence of pure sodium or potassium in corrosion products. These metals will cause skinburns and when bits of the crusty deposit formed on the insulator fell into pools of water on the mine floor an explosive reaction accompanied by flame occurred.

The extent of possible economic effects of these corrosive reactions on the mine transport systems are given.

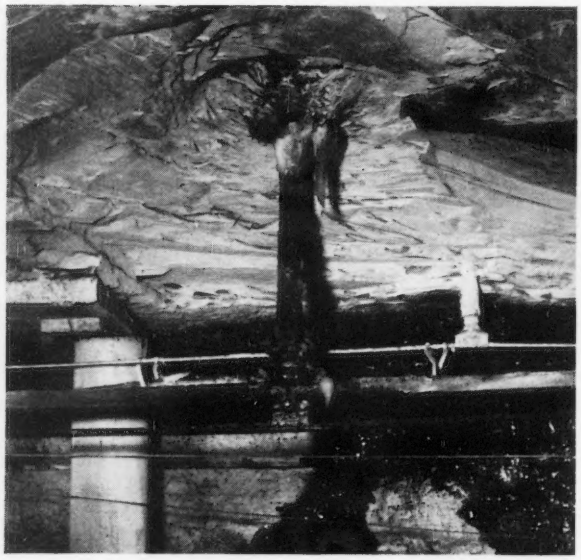

Figure 2—Initial deterioration of rock strata around support of cathodic trolley.

96 mines operating in the United States with positive-polarity grounded traction systems.[2] These mines are distributed as follows:

Pennsylvania	13
Ohio	8
West Virginia	57
Illinois	1
Kentucky	7
Virginia	8
Alabama	2

The traction equipment in mining operations is operated from an electrical power distribution system similar to that of an urban transit system. That is, a DC supply voltage is impressed between a single overhead and insulated trolley wire and the track rails. The track rails are at ground potential which explains why the system is called a grounded system. Compact, portable substations are used as the supply equipment for this DC traction system so that the equipment may be moved from time to time to keep up with expanding operations.

Prior to World War II, DC supply equipment for mining operations almost exclusively employed motor-generator sets, with the positive terminal of the machine usually connected to the trolley wire and the negative terminal connected to the grounded track rail. Thus the conventional system was one of negative-polarity grounding. In the past decade, however, a portable DC power supply unit of the ignitron rectifier type has come into extensive use and with it came the company's first experience with positive polarity grounding.

Ignitron Rectifier

An ignitron rectifier has many advantages over the old motor-generator set, especially regarding efficiency. It also has a peculiar characteristic in that it lends itself readily to positive-polarity grounding.

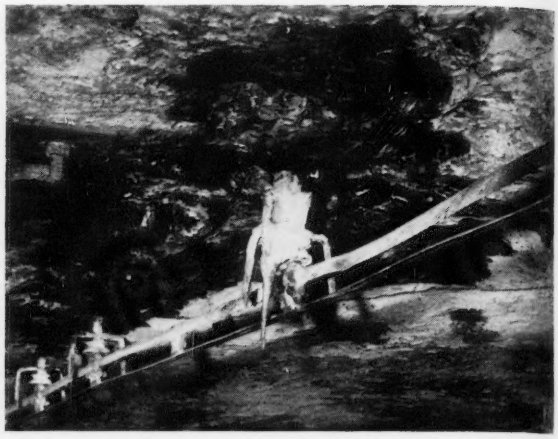

Figure 3—An example of electrolysis product completely bridging insulator.

This is brought about by the method of rectification. In a unit of this type, alternating current is rectified to direct current by ignitron tubes of the mercury arc type, which must be operated within a temperature range of from 10 to 60 degrees C. To accomplish this, each tube is enclosed in a metal tank, force cooled with a liquid coolant from a heat exchanger. This heat exchanger is composed of a radiator, blower, pumps, and piping and must be a self-regulating, integral component of the portable substation.

Electrically speaking, the rectification cycle of the mercury arc tube is such that the tube shell or case is the positive terminal of the DC output. This means that the tube cooling tank is at the positive potential level as will be the components of the heat exchanger also unless they are insulated. Manufacturers of ignitron rectifier substations recommended positive-polarity grounding of traction systems using supply units of this type, especially new mining operations. The reasons for this are as follows:

1. Lower initial costs would be possible because of reduced electrical insulating and shielding requirements.
2. Elimination of possible electrical safety hazards would be possible because all mechanical components of the substation would be at ground potential.
3. Elimination of possible electrolysis in the heat exchanger would be possible because no insulated piping joints would be necessary.

On the basis of these recommendations and also because of unavailability of portable rectifier substations otherwise designed, the company's two most recent coal mine developments used positive-polarity ground-traction systems. Satisfactory operation was obtained for approximately three years. After that excessive failures of trolley insulator hanger assemblies and supports began to occur.

One type of trolley insulator and hanger assembly is shown in Figure 1. This unit is mounted by drilling a hole approximately six inches deep in the roof rock. An expansion bolt is driven into this hole

and the trolley insulator assembly is attached. It is readily apparent that in a typical mine these assemblies, spaced at 10-foot intervals, represent a considerable initial investment, and that frequent replacement because of corrosion would be prohibitively expensive.

Deterioration of Rock Strata

The different stages of deterioration of corrosion that were observed on these assemblies and the adjacent roof rock are shown in the following figures. As can be seen in Figure 2, this corrosive electrolysis action results in the formation of chemical compounds which drip from the roof strata to the trolley. The material is white, crusty, and has a melted appearance; it accumulates in stalactite form, eventually bridging across the insulator to the trolley as shown in Figure 3. The chemicals attack the insulator, completely decomposing it so that it no longer supports the trolley wire.

The rock structure of the roof area adjacent to the mount bolts or supports also deteriorates and loses all its cohesive qualities (see Figures 4 and 5). Eventually the hangar drops and must be removed as in Figure 6. In some cases the roof started falling out in small chips and in other cases it had an appearance like hard mud.

To obtain as much information as possible on this problem, the company did the following things:

1. Chemically analyzed the corrosive formation and roof strata.
2. Conducted stray current and voltage tests along trolley system.
3. Made tests on damaged insulators to determine electrical resistance.
4. Evaluated the dielectric value and hygroscopicity of various types of new insulator assemblies.
5. Checked with manufacturers, NACE, and others in mining industry to determine if this problem had been previously encountered.

Small Leakage Currents

An analysis of the results of the investigation indicated that small leakage currents were causing electrolysis of the rock strata. It was found also that the products of electrolysis were shorting the insulators permitting much higher leakage currents, and much higher rates of electrolysis of the rock strata.

The initial current flow was in the form of leakage current through foreign deposits and moisture accumulated on the insulator face. At first, this current was very low but as the salts of the electrolysis ran down the hanger and across the insulator the leakage current increased and resulted in substantial heating. The rate of electrolysis increased progressively and there was definite evidence that metallic sodium or potassium was being formed; the author, however,

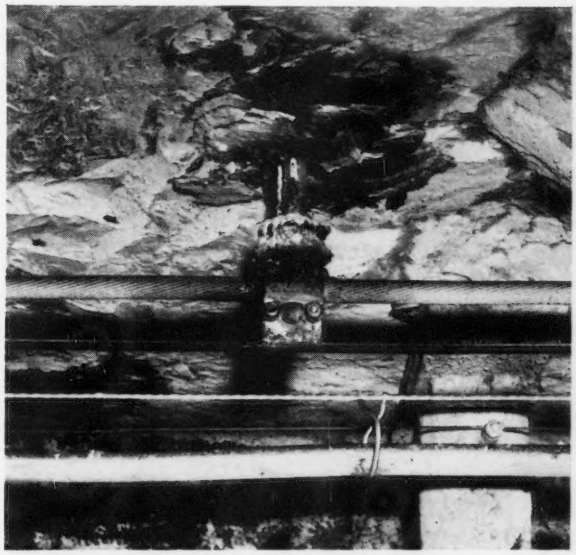

Figure 4—Severe deterioration of rock strata around trolley support.

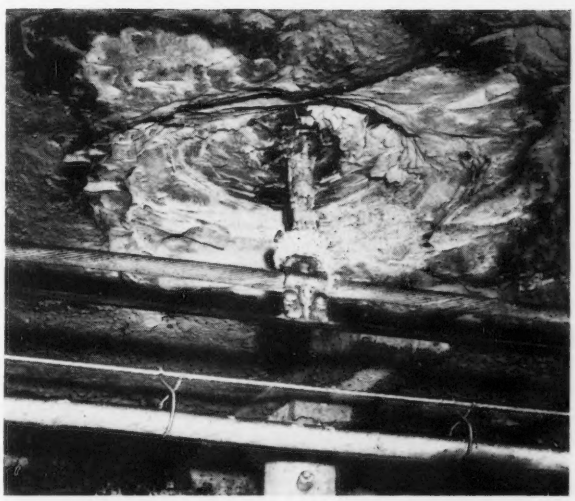

Figure 5—Severe deterioration of rock strata around trolley support (second view).

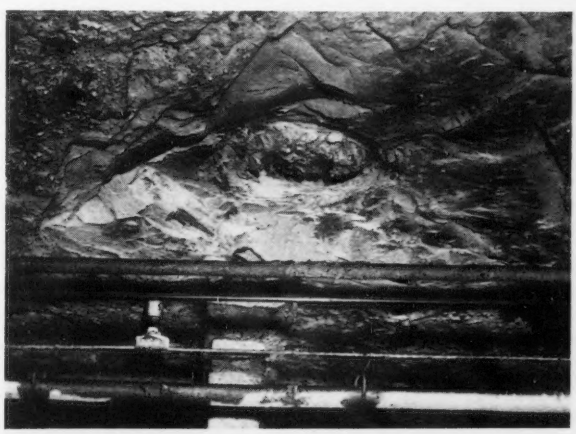

Figure 6—View after trolley support was removed because of deterioration of rock strata.

was unable to detect either metal in the elemental form with the chemical analyses. With the trolley having a negative polarity, the direction of leakage current would be such as to form metallic sodium or potassium at the point of contact between the support and the rock strata. This could occur through a simple electrodeposition process from the fused rock strata.

The chemical analysis of a sample of disintegrated roof rock adjoining the hanger indicated a content of 1.4 percent sodium salts and 2.5 percent potassium salts. The pure metals can cause serious burns if contacted by any part of the body and will react violently when coming in contact with water. This reaction of the pure metal with water has explosive characteristics and results in high-heat liberation. Furthermore, the concentrated hydroxides of these metals can cause skin burns. It was observed that when bits of the crusty deposit formed on the insulator fell into pools of water on the mine floor there was an explosive reaction accompanied by flame. On one occasion on removing an insulator for test in the laboratory, the insulator assembly was accidentally dropped, and a detonation resulted similar to that occurring when a .22 caliber bullet is fired. In another instance particles of the corrosive material were removed from a corroded assembly; when water was thrown on the particles, they burst into a blue flame.

Conclusions

The company's experiences with the system have brought out these pertinent facts:

1. Excessive insulator failure is in its entirety due to making the trolley wire negative to ground so that leakage current across the hanger assembly permits a cathodic reaction at the support. In an average mine using 5000 of these assemblies, the replacement and maintenance costs would be abnormal. It was observed for example that the leakage current alone in this mine represented a consumption of approximately 1100 kilowatt hours per day .

2. It does not appear feasible to completely prevent leakage currents. Numerous tests were conducted on new and conventionally designed trolley insulator and hanger assemblies from various manufacturers. These tests indicated that the insulators were, in the majority, highly hygroscopic. For example, one insulator tested initially with a 1000 volt megger had an insulation resistance of 2000 megohms, but after the insulator and skirt was dipped in water and slung dry, the insulation resistance meggered only 200 megohms and two hours later only 400 megohms. It is the author's belief that the basis for design of this insulator has been the dielectric strength of the material for which the standard requirement is ten times the line voltage plus 1000 volts. In reality this represents the resistance to electrical puncture, which in the mining industry is relatively unimportant as line voltages seldom exceed 300 volts. It is the author's opinion that hygroscopic characteristics are equally important and should be a prerequisite of design, regardless of type of grounding.

3. The most important factor in considering this type of grounding system is safety. No other industry so rigidly enforces safety or conducts such extensive checks and studies to improve safety conditions as does the mining industry. The presence of a condition that may result in the deposition of sodium or potassium in a pure state is certainly unwelcome, and not in keeping with standard safety practices. Although the company has had no serious trouble attributable to this condition, the possibility of such an occurrence is one that should be eliminated at all costs.

As previously stated, the company has completely converted to a grounded negative system the only two of its mines designed for positive-polarity grounding. It is recommended that others in the industry so affected do likewise. The disadvantages now becoming apparent in such a system far offset the initially proposed advantages.

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Any discussions of this article not published above will appear in the June, 1956 issue

Oxide Films on Stainless Steels*

By THOR N. RHODIN

1. Introduction

PASSIVITY HAS BEEN defined[1] as a condition of a metal surface characterized by resistance to corrosion in media where chemical attack would be predicted on the basis of thermodynamical considerations. This phenomenon is a surface effect localized at the metal-liquid interface and is unique to a specific group of metals and alloys including the stainless steels.

Two of the most plausible interpretations of this effect involve a presumption that critical importance must be attached either to adsorbed layers[2,3] or to ultra-thin oxide films.[4,5] It is proposed by the author that both of these effects are critical in defining passivity. It is proposed also that the extent of passivity is determined by the unique manner in which molecules of dissolved gas and ions from solution are bound to this ultra-thin but discrete phase at the interface.

This hypothesis will be examined briefly. The strong residual bonding forces characteristic of freshly formed steel surfaces readily produce adsorbed layers of gas and reaction-product film. It is not surprising that experimental evidence points to the presence of both adsorbed layers and oxide films on stainless steel surfaces.[3,5] Although substantial theoretical and experimental effort has been made to establish the relative importance of these two phenomena, there is still doubt as to which one is most critical.[1] Interpretations based on the adsorption-hypothesis are plausible enough but often they are not sufficiently encompassing. With certain exceptions[4,6] such interpretations lack a sufficiently detailed evaluation of the stability of adsorbed layers, the character of the surface, the kinetics of interaction between the adsorbate and adsorbent, and the specific influence of these effects on the extent and reversibility of passivity. It remains to be established whether adsorption phenomena alone provide necessary and sufficient conditions for defining passivity. Similar uncertainty exists in defining the exact role of oxide films.

The Generalized Film Theory[1] of passivity emphasizes the importance of oxide films. Recent studies[5,7] have postulated that corrosion-resistant surfaces are characterized by oxide films of unique compositional and structural properties. Definite experimental evidence supports this hypothesis, but more remains to be clarified with reference to the mechanism by which these films form and maintain themselves during corrosion. The importance of oxidized layers in diminishing corrosion for stainless steels in gas atmospheres at elevated temperatures[8,9] is accepted. In comparison, the importance of films with respect to corrosion resistance in aqueous systems at moderate temperatures is much less obvious.

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Abstract

Oxide films on stainless steels have been classified into three types according to film thickness, film structure, film composition, and influence of the film on resistance to corrosion.

Compositional properties of oxide films isolated from surfaces of stainless steels were studied using specially developed microanalytical techniques. Properties of passive films on stainless steel were evaluated and the effects of alloy composition and surface treatment on other types of films on Types 304, 316, and 347 stainless steels were studied.

The influence of corrosion in various media was correlated with film compositional properties. Composition of films after immersion in acids was found to be related to film composition prior to immersion. The effect of immersion depended on the nature and intensity of corrosion and was reflected most sensitively by the iron and silicon contents of the films.

The conclusion was made that film properties indicate strongly the capacity of austenitic stainless alloys to develop corrosion-resistant surfaces in certain environments.

Some aspects of this concern may be framed in the following questions.

1. Are the properties of the oxide film importantly related to the corrosion mechanism or are they an incidental by-product of the reaction?
2. Are these properties unique for each metal-liquid interface or are they insensitive to alloy composition and corrosive medium?
3. If film properties are unique, what is their relationship to the mechanism by which self-protection develops?
4. Assuming film properties to be critical, are the structural or the compositional ones most important?
5. What are the relationships between the following different films: those formed by pretreatments (passivation), those formed during service (immersion in the corrosive medium), and those formed at local areas of breakdown in the film (during service)?

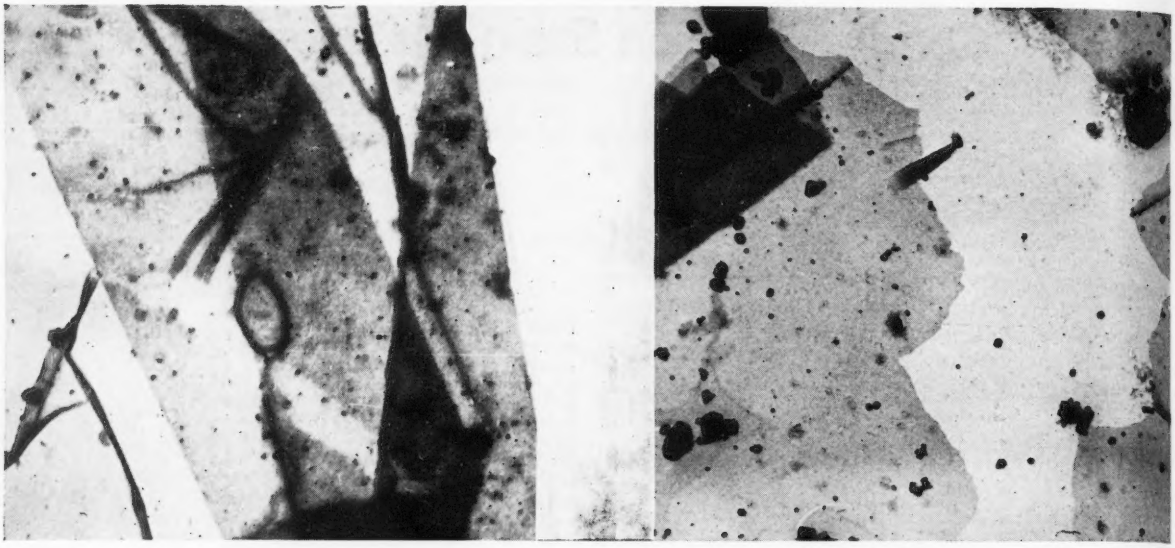

Figure 1—Comparisons of structures for Type-1 and Type-2 oxide film. At left is an electron micrograph at 18,500X Type-1 oxide film isolated from Type 316 stainless steel. At right is an electron micrograph of Type-2 oxide film under same conditions and same magnification.

Experimental data are not available for evaluating all of these points in this paper. Some clarification of them can be obtained, however, by consideration of film properties for some specific stainless steels in terms of alloy composition, surface treatment, and corrosive media.

First, it is desirable to make some distinctions among types of oxide films normally encountered. They can be divided for convenience of discussion into three general categories. The following properties have been considered in making the classification: film thickness, film structure, film composition, and influence of the film on corrosion resistance.

1.1. Classification of Oxide Films

1.1.1. Ultra-Thin Films. These films are most effective in the thickness range from 30 to 60 Å. They are usually produced on freshly prepared stainless steel surfaces by treatment in oxidizing acids or atmospheres for short times at moderate temperatures.[10] No fine structure can be resolved with the electron microscope[5, 7] and no definable crystallinity has been definitely established by electron diffraction studies of isolated film.[5]

Ultra-thin films are composed of a mixture of flocculent oxides of the transition metals (iron, chromium, molybdenum, etc.) and include amorphous silica in some cases. Water is an important component of the film but is not combined in any fixed proportion. Their gel-like properties[2, 7] provide an enhanced capacity for holding adsorbed gases and ions in close proximity to the underlying metal. Proponents of the adsorption-hypothesis have only indirectly considered the adsorptive nature of Type-1 film in interpretation of adsorption studies.

The structure and composition of these films are very sensitive to their environment. They are colorless and visible only when isolated from the metal and viewed in indirect light. Their presence is often unobserved. This makes them particularly difficult to isolate and to characterize. Their composition is associated with enrichment in certain minor alloying elements but not necessarily with that of chromium and nickel. The mechanism of formation is probably associated with the selective dissolution and deposition of reaction products from solution. Type-1 films are most effective in corrosion systems containing dissolved gases in aqueous solutions at moderate temperatures.

1.1.2. Colored Films. These are the films most customarily observed (they produce interference colors upon reflection of light from the metal surface[11]). Their contribution to corrosion resistance is easy to confuse with that of the Type-1 films which often exist underneath, next to the metal. Type-2 films are approximately 300-500 Å thick and have been shown to have definite crystallinity, often of the cubic spinel type.[5, 8] These films differ distinctly in both structure and composition from the Type-1 films associated with passivity effects. Type-2 films are brittle and grainy as illustrated by electron micrographs (Figure 1) taken by Mahla and Nielsen[5] of the two types of films isolated from Type 316 stainless steel. Type-2 films have been widely studied and are completely reviewed by Evans.[11] They form in hot oxidizing acids and are also associated with oxidation resistance of the underlying metal to gaseous atmospheres at elevated temperatures.[8, 12]

Considerable study has been done in connection with the structural relationship of Type-2 film to the base metal and pseudomorphic effects on adherence and film growth.[9, 11, 13] The mechanism of formation is associated with transport of metal and oxygen ions through the oxide lattice by solid diffusion.[14, 15] Their crystalline structure is characterized by lattice defects.[16] Film growth often is accompanied by an accumulation of bulk stresses which cause fracture and sometimes recrystallization of the film.

Many solid-state reactions occur in Type-2 films

such as auto-reduction of one oxide by another metal, or transitions of oxidation toward higher oxidation states located at the oxide-oxygen interface.[17] These processes tend to develop film compositions enriched in those metals of higher mobilities and more stable oxidation states such as chromium. Water is not an important component on Type-2 films.

1.1.3. Oxide Scales. Scales constitute Type-3 films. Lustman[18] has made a critical review of oxide scales. A comparison may be made between passive films (Type 1, 30 Å), heat-tinted films (Type 2, 300 Å), and scales (Type 3, 1000 Å).

Scales are almost always composed of segregated layers of different oxides in many oxidation states and combinations with each other.[19] Their structural properties are closely related to those of bulk oxides. Their strong tendency to spall makes it easy to isolate and examine them. The ability of such scales to protect the metal from progressive oxidation at high temperatures consists of a bulk screening effect. They are often separated from the metal by much thinner films with properties intermediate between those of Type-1 and of Type-2 films. Because the rate-determining step in Type-3 film growth is often localized at an interface, the thickening properties of Type-3 films may often be controlled by the presence of much thinner layers adjacent to the metal.[20] Although Type-3 films are important in some aqueous as well as many gas phase operations, only Type-1 and Type-2 films will be considered here inasmuch as they are more characteristic of the surface chemistry of the metal itself.

Much of the excellent early work on oxide-film properties is carefully reviewed by Kubaschewski and Hopkins.[16] This work emphasized structural and film-growth studies on Type-2 and Type-3 films.

Investigation of compositional properties was pioneered by Evans[11] and carried on by Vernon et al.[21,22,23] starting in 1939 in England. Gulbransen, Phelps and Hickman[24] and Mahla and Nielsen[5] pursued the study in this country. Experimental difficulties have tended to limit compositional studies to films at least several hundred Angstroms in thickness although the importance of extending this work to ultra-thin layers of the Type-1 class has been appreciated for some time. Improvements in microanalytical techniques and instrumentation have now made possible a systematic extension of film characterization studies to Type-1 film.

1.2. Proper Interpretation of Film Data

Caution should be exercised in the interpretation of data on oxide films. There exist, of course, uncertainties characteristic of the experimental techniques themselves. Assuming these uncertainties to be adequately minimized and controlled, interpretation of corrosion processes based on compositional data alone can be misleading. Such data are most reliable when used in conjunction with information on film structure and corrosion rates. It is desirable to point out the following five limitations of film-compositional data taken alone:

1. Although film compositions are usually reported in terms of weight percent of the metallic elements present, the elements are known to be combined with oxygen and water, and in some cases, with each other.[7]
2. The enrichment of minor elements such as silicon, molybdenum, or niobium, is striking, but other elements such as chromium and nickel are also important film constituents in spite of the fact that no significant enrichment occurs for them in some cases.[7]
3. Thin oxide films often show striking enrichment effects inasmuch as relatively little redistribution of elements between the alloy and the film is required to affect considerably the composition of the film. Considerable care must be taken to eliminate the possibility that inclusions in the film are masking its true composition. Optical and electron metallography are extremely useful in resolving this uncertainty.
4. It is essential that distinction be made between films associated with the corrosion resistance of the surface, and corrosion products which may have a very minor effect on protection. It is not always possible to make this distinction as, for example, after severe pitting corrosion. Products deposited in cavities formed by undermining of the surface can introduce uncertainty in the interpretation of the film data. The same analytical techniques can be used, however, for isolating and characterizing the corrosion deposit. The problem here is essentially that of sampling and interpretation.
5. The influence of films on corrosion is strongly affected by the physical properties[19] of the film, such as permeability, adherence, stratification, and homogeneity. These factors should always be considered in the proper interpretation of compositional film data.

2. Instrumentation and Technique

The experimental procedure used in the characterization of oxide films can be divided into the following three general stages:

1. Reliable and representative sampling of the surface.
2. Measurement of physical data on isolated film.
3. Interpretation of the data in terms of related corrosion properties.

Factors influencing the proper interpretation of the data already have been pointed out. Sampling and measurement procedures on tenuous films are very susceptible to error from contamination and can be difficult. They must be carefully tailored to match the peculiar properties of each type of sample.

2.1. Isolation of the Film

Sampling a surface of a metal to yield representative material free of inclusions and other contaminants is one of the most difficult operations in the study of isolated films. The problem of error introduced by consideration of films spuriously produced during sampling is not included here. Considerable evidence[5,7] indicates that this is not a legitimate criticism in cases where proper sampling procedures are followed. Useful surface sampling methods may be classified according to the main operation used as mechanical, chemical or electrolytic.

Mechanical methods include the use of microtomes, abrasives and cutting tools to remove material from the surface. Most of these methods suffer not only from limitations in the minimum depth of sampling

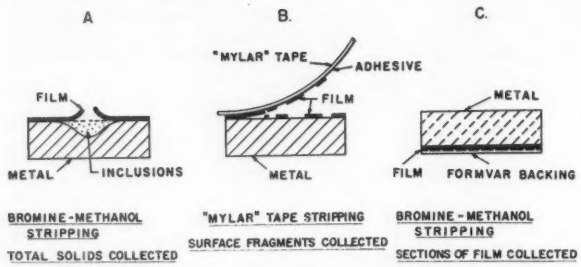

Figure 2—Comparison of surface sampling methods.

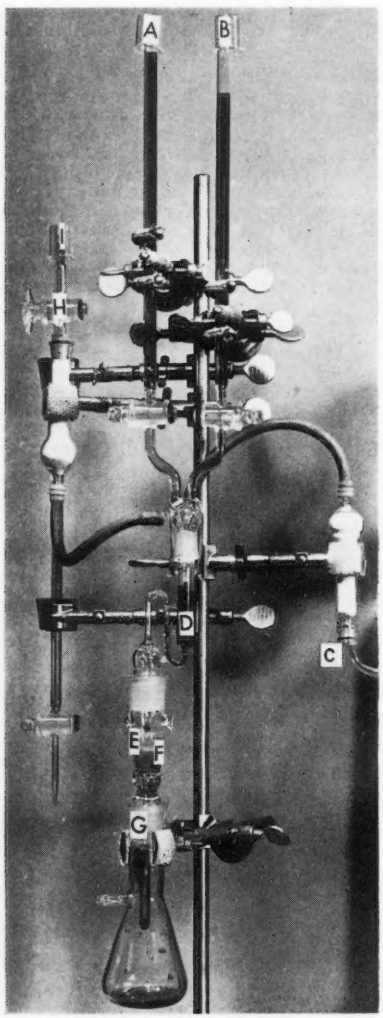

Figure 3—Film stripping apparatus.

attainable but from hazards of contamination and non-uniformity caused by localized heating, surface flow, or solid diffusion. These methods have the advantage of avoiding complications from solution reactions and chemical side-effects.

A compromise method (the "Mylar"-tape technique) successfully avoids these difficulties. The adhesive side of the tape is rolled hard against the oxidized surface. Fragments of film are removed from the metal by quick stripping of the tape as illustrated in Figure 2b. Film fragments are subsequently removed from the tape using a micro-extraction apparatus. Samples are small (10×10^{-6} gram) but remarkably representative of the surface, as indicated by comparison to other methods.[7]

Chemical methods in which aggressive reagents are used to attack the metal and float the film away were developed by Evans and coworkers.[11] The undermining effect is illustrated in Figure 2a. Vernon, Wormwell, and Nurse[22,25] demonstrated the effectiveness of this technique by providing for the exclusion of moisture and oxygen from their apparatus.

Mahla and Nielsen[5] were the first to isolate passive film from stainless steel surfaces by use of a bromine-methanol reagent. An anhydrous methanol-bromine solution in an atmosphere of deoxygenated nitrogen was used also by the author[7] in a specially designed all-glass stripping apparatus (see Figure 3) similar to the type originated by Vernon and coworkers.[22] The procedure involves bubbling deoxygenated nitrogen (C) over a coupon of metal (1 inch x 1 inch x ¼ inch) located in the reactor (D). Burettes containing stripping solution (A) and wash liquid (B) connect directly to the reactor (D). Film fragments are siphoned from (D) to (E) and collected on a filter disk (F) from which they are removed for analysis. Excess liquid and dissolved metal are collected in (G).

The effectiveness of the technique was greatly improved by establishing conditions in which film could be stripped without contamination by insoluble inclusions such as silica.[7] The reliability of this sampling technique can be monitored by stripping silicon-free steels with both chemical and mechanical techniques. In no case is silicon detected in excess of the normal blank corrections for these steels when proper stripping conditions are employed. Careful evaluation of this technique has served to establish the reliability of the surface sampling techniques used.

Electrolytic methods were first applied by Evans[11] and later extended by his coworkers[26] to remove oxide films from iron, copper, nickel, carbon steel, and stainless steel. Phelps, Gulbransen, and Hickman[24] have successfully removed oxide films from many metals and alloys using electrolytic techniques. Care must be taken to eliminate electrode reactions during stripping which might contaminate or destroy the film.

2.2. Characterization of Film

The importance of correlating film data obtained by electron metallography and electron diffraction with compositional data has been pointed out. Use of only one of these methods without cross-evaluation can be misleading. For example, the distribution and intensity of lines in a diffraction pattern are not necessarily proportional to the quantity of material present. This is especially true for multicomponent samples such as films from stainless steels.[2]

In recognition of this, workers in the field seek to supplement their structural studies of isolated films with compositional data as much as possible. In addition, studies[27] have shown that certain film com-

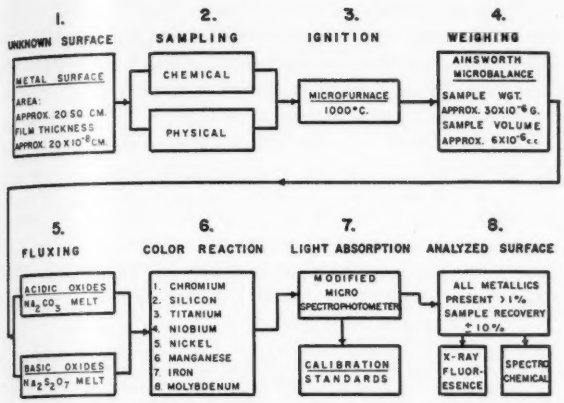

Figure 4—Microanalytical method simplified flow chart.

ponents such as amorphous oxides may not show up in diffraction patterns at all. Finally, diffraction patterns characteristic of Type-1 films may differ considerably from the established standard patterns characteristic of bulk oxides.

Interpretation of compositional film data is limited also when examined alone inasmuch as no information on the combination of the film components is provided. For example, the presence of silicides in films on Duriron[7] was detected by diffraction studies, whereas compositional data merely indicate the quantities of iron and silicon present.

The cubic spinel structure of Type-2 films on stainless steels also was demonstrated[5,8] by diffraction studies. Fontana[2] has made ingenious efforts using electron diffraction data to evaluate the structural properties of artificially produced oxide deposits. In all of this work the instrumentation used in the structural studies is superior to that used in associated compositional studies. The need for improving compositional measurements on Type-1 films has long been recognized.

A reliable analytical procedure has been established to make possible this improved measurement.[7] It consists of a series of consecutive microchemical operations in which the isolated film is washed, ignited, weighed, fused, leached, and finally analyzed spectrophotometrically. The flow-chart in Figure 4 summarizes the general operation. Most of the techniques used are derived from classical procedures in microanalysis. Details of the actual techniques are described elsewhere.[7]

Reproducibility of the data is illustrated by the dispersion of a typical group of analyses for passive film in Figure 5. The film is formed by treating a freshly pickled surface of Type 304 stainless steel in 5 percent HNO_3 — 0.5 percent $K_2Cr_2O_7$ for 20 minutes at 60 C. The effectiveness of the techniques can be appreciated when it is realized that Type-1 films are often less than one-millionth of an inch in thickness. Samples weighing 10 to 50 x 10^{-6} gram must be manipulated on a quantitative basis. The spectrophotometric method required conversion of the film samples to water-soluble form, separation of interfering elements, and the application of sensitive color reactions.

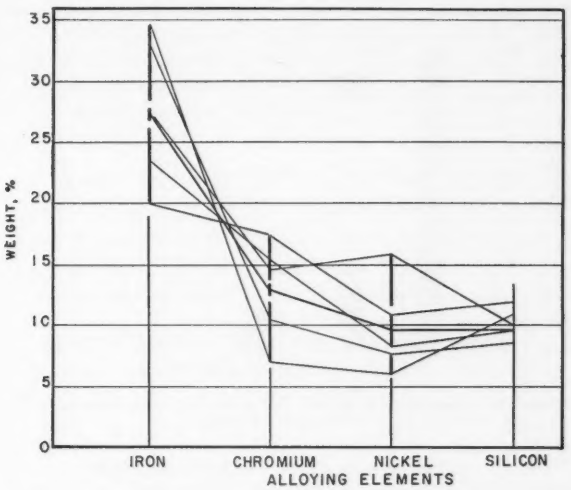

Figure 5—Typical dispersion in analytical data for passive film composition.

An additional physical technique which requires considerably less manipulation of the sample is x-ray fluorescence analysis. Chemical analysis of films by x-ray fluorescence techniques has proved very useful. The method consists essentially of isolating oxide film backed by "Formvar" and supported on very thin (0.00025 inch) "Mylar" film as illustrated in Figure 2c.

The sample is irradiated with polychromatic x-rays from a tungsten target. Measurement of the wavelength and intensity of the emitted radiation yields accurate data on the metallic composition of Type-1 and Type-2 films. The data compare favorably with those obtained independently by more elaborate analytical procedures. Typical data obtained by the two methods for passive film isolated from Type 304, 316, and 347 stainless alloys are discussed in the following section.

3. Properties of Oxide Films Isolated from Austenitic Stainless Steels

It would be well to examine some of the properties of oxide film on stainless steels on the assumption that they substantially influence the resistance of the steel to corrosion in aqueous solutions at moderate temperatures. The films in general are considered to be homogeneous except for defective areas where accelerated attack may become localized. The ability of stainless steel surfaces to heal such defects as they develop varies considerably with the alloy composition and the corrosive medium.

A second assumption is made that studies of very thin oxide films are important in characterizing the corrosion resistance of a stainless steel because they indicate the inherent self-passivating properties of the surface. This concept broadens the scope of film studies considerably because it does not necessarily require that the oxide film itself be the prime cause of corrosion resistance. It provides a new tool for characterizing those applications of metals and alloys which depend on the chemical properties of the surface.

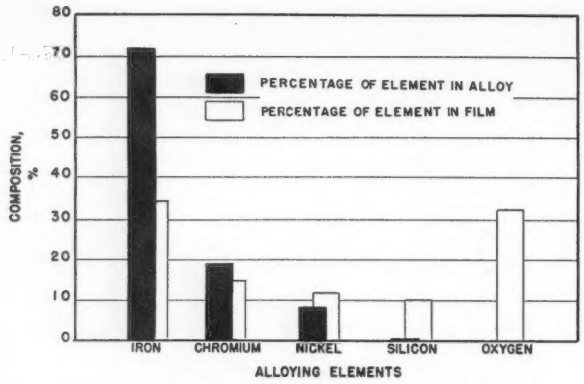

Figure 6—Comparison of passive film and alloy compositions on Type 304 stainless steel.

TABLE 1—Compositions of Stainless Alloys[1]

AISI Type	% Cr	% Ni	% Si	% C	% Mo	% Nb	% Mn	% S
304	18.6	9.4	0.26	0.05	...	...	0.90	0.019
304	18.4	8.8	0.29	0.06	...	...	0.59	0.025
304	17.6	10.1	0.41	0.06	...	...	1.73	0.014
304	18.6	10.7	0.49	0.05	...	...	1.54	0.019
304	18.3	8.7	0.61	0.07	...	...	0.75	0.008
304	18.4	9.9	0.66	0.07	...	...	...	....
304	17.9	8.6	0.88	0.09	...	.....	0.85	0.015
304	19.9	9.6	1.56	0.08	...	...	1.25	0.012
304	18.2	8.8	1.89	0.09	...	...	0.92	0.014
304[2]	20.6	9.0	...	...	...	...	...	....
316	17.6	13.0	0.60	0.08	2.3	...	0.77	0.006
316[2]	19.6	11.3	1.20	...	1.3	...	...	....
347	18.2	10.8	0.64	0.04	0.2	0.64	1.30	0.009
374[2]	18.8	10.2	0.86	...	0.03	0.16	...	....

[1] Balance, iron.
[2] Alloy-films formed by vacuum evaporation.

3.1. Passive Films (Type-1)

Data on passive films formed on various typical stainless alloys (alloy compositions are listed in Table 1) are in agreement with predictions that film composition is unique for each alloy. Type-1 oxide films formed by passivation of bright-pickled foil or strip were isolated and characterized using techniques previously described. A standard pretreatment consists of a pickle in 10 percent HNO_3 — 2 percent HF — 1 percent HCl solution at 80 C for one minute. Passive films were formed by exposure to oxygen or to filtered air at 25 C for 30 minutes or to 5 percent HNO_3 — 0.5 percent $K_2Cr_2O_7$ solution at 60 C for 30 minutes.

3.1.1. Compositional Properties. Compositional data for Type-1 film from Types 304, 316, and 347 stainless steels were determined independently by x-ray and colorimetric analytical methods. Film composition is uniquely different from that predicted by proportional oxidation of the alloy. Film compositions also vary distinctly with alloy composition as indicated in Table 2. A bar chart comparison in Figure 6 illustrates the degree to which the distribution of alloying elements can vary between the alloy and the film for Type 304 stainless steel. Iron is depleted by 50 percent and silicon is enriched by a factor of 20. Because more oxygen is associated with silicon than iron per unit weight, the enhanced silicon and oxygen contents tend to balance the depletion of iron.

It is significant that passive films of this type show no film enrichment in chromium. In addition, no significant redistribution in nickel is observed. Silicon, which is normally present only as a minor constituent, shows the greatest degree of enrichment. Film enrichment in chromium does occur for other films but is not typical of ultra-thin films formed in air or nitric acid mixtures. Films of Type-2 character formed in other ways are indeed enriched in chromium as previously reported.[19] After considerable study of known sources of silicon, the presence of significant quantities of silica in the passive film also was definitely established.

The importance of water as a component of isolated films was studied because of the fact that many protective films are known to form only upon exposure of metal to media containing at least small quantities of water. It was concluded that water is an important component of passive films on stainless steels. There can be as much as 30 percent water by weight prior to ignition with the determining factor being the nature and temperature of the medium in which the film forms.[7] Transitions in the appearance of the film can be observed as water is absorbed or desorbed. These changes are associated with structural changes.

It is likely that corresponding structural transitions in the film while on the metal influence the protective nature of the film. This effect has been demonstrated for protective films on aluminum.[28] The water content of passive film on stainless steel was most sensitive to temperature.

The metallic composition of the films was unique for each alloy as indicated by corresponding data for Types 316 and 347 stainless steels in Table 2. Films on Type 316 steel contain more iron and less nickel than those on Type 304. Some enrichment in molybdenum is observed. Films on Type 347 stainless steel also show a corresponding higher iron content than those in Type 304 steel with enrichment in chromium and nickel contents intermediate between those for films on Types 304 and 316 steels. A definite enrichment of niobium in the film also is observed on Type 347 steel.

Significant enrichment of silicon in the film is observed for all three alloys. The compositions of air-formed films are similar to those of films formed by acid passivation with some exceptions. The iron contents of the air-formed Type-1 film run higher than those of the film formed by acid passivation, indicating that iron oxide formed on the surface during pickling may be removed during the acid passivation.

It is interesting to note that this effect is greatest for Type 347 steel. Films formed by acid passivation also show a small chromium enrichment compared to films formed by air passivation. This effect is greatest for Type 347 compared to Types 316 and 304 stainless steels.

3.1.2. Structural Properties. The importance of correlating compositional with structural data in characterization studies on isolated oxide films already has been emphasized. Type-1 films from Types 304, 316,

and 347 stainless steels studied with the electron microscope (at 25,000 X) are of the very thin (approximately 50 Å), homogeneous kind, remarkably free of dispersed inclusions. Their properties have been reported by Mahla and Nielsen.[5] Films containing water have gel-like properties which disappear during dehydration.

Study of the isolated films by electron diffraction yields diffuse patterns indicative of a finely crystalline nature approaching an amorphous state. Some typical electron diffraction data for Type-1 films formed on both foil and evaporated surfaces of Type 304 stainless steel are summarized in Table 3. The patterns are diffuse for both surfaces although the fine-grained undistorted surface of the evaporated metal produced a somewhat more crystalline passive film.

Fontana[2] has pointed out the resemblance of Type-1 films to hydrous oxides. The patterns actually fit that characteristic of a hydrous mixed oxide-silicate. On the other hand, as indicated by Mahla and Nielsen,[5] Type-2 films are definitely characterized by cubic spinel structures. Diffraction studies of Type-2 films by Gulbransen, Phelps, and Hickman[24] have yielded much data on the crystallinity of many types of oxide films.

TABLE 2—Composition of Type-1 Oxide Films Isolated From Austenitic Stainless Steels and Analyzed by Microcolorimetry and X-Ray Fluorescence

Steel	Film Sample[1]	Method	% Fe	% Cr	% Ni	% Si	% Nb[2]	% Mo[2]
Type 304	Stoich. Oxide	Calculated	49.8	12.8	6.6	0.5	....	....
Type 304	Air-Formed Film	Colorimetric	49.2	15.2	6.0	10.1	....	....
Type 304	Air-Formed Film	X-ray fluor.	50.1	14.1	4.4	....	....	....
Type 304	Passive Film	Colorimetric	34.0	14.0	10.7	9.9	....	....
Type 304	Passive Film	X-ray fluor.	37.2	13.4	9.4	....	....	....
Type 316	Stoich. Oxide	Calculated	50.6	8.4	6.8	0.5	0.63	1.4
Type 316	Air-Formed Film	Colorimetric	49.5	12.3	6.2	....	....	0.2
Type 316	Air-Formed Film	X-ray fluor.	53.4	11.2	3.1	....	....	0.3
Type 316	Passive Film	Colorimetric	45.0	13.0	5.4	14.5	0.20	4.2
Type 316	Passive Film	X-ray fluor.	42.1	12.6	4.9	....	....	1.2
Type 347	Stoich. Oxide	Calculated	52.2	9.5	6.3	0.5	0.45	0.1
Type 347	Air-Formed Film	Colorimetric	53.1	10.8	4.8	....	....	0.9
Type 347	Air-Formed Film	X-ray fluor.	60.2	8.5	4.1	....	....	....
Type 347	Passive Film	Colorimetric	44.5	20.7	8.2	12.9	5.70	....
Type 347	Passive Film	X-ray fluor.	45.4	17.7	7.7	....	....	....

[1] Typical values obtained for equivalent films, 2 to 4 determinations; typical sample weight, 50 micrograms.
[2] Niobium and molybdenum data obtained by x-ray fluorescence are uncertain.

TABLE 3—Electron-Diffraction Data[1] on Oxide Films From Type 304 Stainless Steel

Type-1 Film[2]	Type-2 Film[3]	Type-2 Film[4]	Spinel Oxide[5]	Silica Hydrate[6]
.....	2.99 w	2.99 s	2.96 s	3.01 w
2.50 s	2.51 vs	2.48 vs	2.53 vs	2.56 vs
2.07 s	2.08 s	2.08 vs	2.08 vs	2.06 s
.....	1.60 m	1.62 m	1.60 m	1.59 m
1.46 s	1.47 s	1.48 vs	1.49 vs	1.49 s
.....	1.26 m	1.28 s	1.28 s	1.28 s
1.17 w	1.19 w	1.20 m	1.22 m	1.15 w
.....	1.08 s	1.10 s	1.10 vs	1.06 s
.....	0.92 w	1.05 s	1.05 s	.....

[1] Values are expressed in Angstroms; letters following numbers indicate estimated line intensities as follows: vs = very strong, s = strong, m = medium, w = weak.
[2] Passive film formed on foil samples. Diffuse patterns similar to those previously obtained by Mahla and Nielsen (See Reference No. 5).
[3] Film formed on evaporated samples. Pattern diffuse but readable with accuracy. Classification of film-type uncertain.
[4] Thick film formed on foil samples by heat-tinting in molten $NaNO_3$-KNO_3 for 1 minute. Sharp rings. (Approximate thickness, 350 Å.).
[5] Reference x-ray pattern for mixed oxide spinel (Fe_3O_4 with NiO and Cr_2O_3).
[6] Reference x-ray pattern for metal oxides-silica hydrates (Fe_3O_4(NiO, Cr_2O_3) $SiO_2 \cdot H_2O$).

3.2. Films of Intermediate Thickness (Type-2)

3.2.1. Characteristics Associated with Film Growth. The general properties distinctive of Type-1 and Type-2 films on metals have been outlined on the basis of structure, composition and corrosion-resistance. Tylecote[29] in his review of oxide films on copper has pointed out significant trends in film properties associated with growth. Analogous trends will be considered in terms of film properties associated with the transition from Type-1 to Type-2 film character for stainless steel.

Changes in structure are characterized by an increase in crystallinity, graininess, and brittleness. A corresponding change in composition and corrosion data[5] on Type 304 stainless steel using a standard passivation treatment (see Sample 3a, Section 4.1) for increasing times of immersion is indicated in Figure 7. Weight loss occurring in 10 percent $FeCl_3$ solution after 144 hours at 25 C is indicated.

Examination of Figure 7 indicates that corrosion-resistance is observed to decrease with increasing film thickness. A corresponding transition in film properties is also observed. In addition to the changes in structure, a distinctive decrease in the water content occurs. In addition, silica as a film component approaches a value much closer to that characteristic of the alloy than Type-1 film. This indicates that the mechanism of Type-2 film growth does not involve the same enrichment in silica that is observed in the formation of Type-1 film. It is also significant that Cr_2O_3 has become a major film component for Type-2 films.

The compositional changes occurring during the film growth are distinctive, as illustrated by some typical data for Type 304 stainless steel in Table 4. As the film thickens, depletion in iron and nickel commences. Enrichment of chromium becomes much more im-

TABLE 4—Effect of Surface Treatment on Film Composition[1] for Type 304 Stainless Steel[2]

Treatment	Film Thickness[3] (Å.)	% Fe	% Cr	% Ni	% Si	Film Type
Stoichiometric Oxide[2] (calculated)	.....	49.8	12.8	6.6	0.5	Bulk
High Temperature[4] Oxidation (900 C)	800 ± 100	15.2	41.3	3.5	2.0	3
Nitrate Melt Oxidation[2] (300 C)	350 ± 50	15.1	46.6	4.0	3.3	2
Cold Rolling[2] Oxidation (200 C)	150 ± 50	20.1	32.2	6.6	5.0	2
Acid Pickling[2] (80 C) Oxidation	60 ± 15	22.2	17.0	7.2	11.5	1
Acid Passivation[2] (60 C)	45 ± 10	34.0	14.0	10.7	9.9	1
Air Passivation[2] (25 C)	35 ± 10	49.2	15.2	6.0	10.1	1

[1] Values revised from the following Reference: T. N. Rhodin—*Ann. N.Y. Acad. Science*, **58**, 855 (1954)
[2] Alloy Composition: 18.6 Cr—10.7 Ni—0.49 Si—0.05 C—1.54 Mn—0.019 S—Bal. Fe.
[3] Estimated values.
[4] Alloy Composition: 27.9 Cr—0.08 Ni—0.54 Si—0.05 C—0.38 Mn—Bal. Fe.

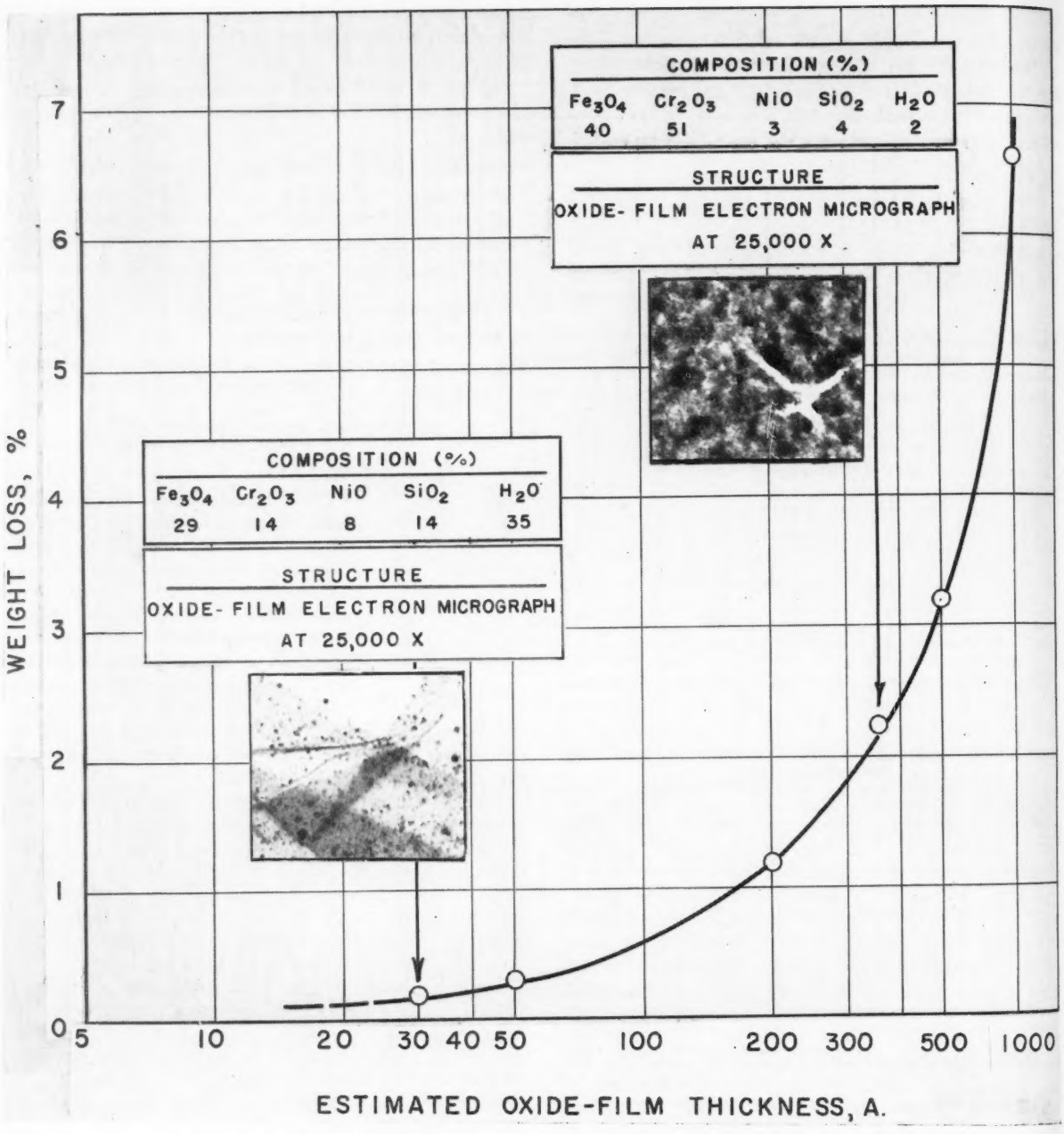
COMPOSITION (%)
Fe3O4 Cr2O3 NiO SiO2 H2O
40 51 3 4 2
STRUCTURE
OXIDE- FILM ELECTRON MICROGRAPH
AT 25,000 X
COMPOSITION (%)
Fe3O4 Cr2O3 NiO SiO2 H2O
29 14 8 14 35
STRUCTURE
OXIDE- FILM ELECTRON MICROGRAPH
AT 25,000 X
WEIGHT LOSS, %
0 1 2 3 4 5 6 7
5 10 20 30 40 50 100 200 300 500 1000
ESTIMATED OXIDE-FILM THICKNESS, A.

Figure 7—Weight loss in 10 percent ferric chloride solution at 25 C after 144 hours.

portant in defining film properties. Silica and water are observed to assume minor importance. Other data indicate that these effects are illustrative of general trends although variations will occur, when conditions such as the medium used to produce the film are changed. For example, Type-2 films formed by air-tinting are depleted more in iron than those formed by prolonged immersion in nitric acid. The fact that this effect is opposite to that observed for Type-1 films is associated with a different mechanism of film formation.

3.2.2. **Effect of Surface Treatment.** The general effect of surface treatment on film composition is summarized in Figure 8 for Type 304 stainless steel. All treatments produce films containing less iron than predicted by proportional oxidation of the alloy. Those formed at the higher temperatures under conditions yielding thick films (intermediate between Type-2 and Type-3) show the most substantial iron depletion relative to the stoichiometric oxide.

Chromium shows a marked surface enrichment after treatment at high temperatures or where substantial surface deformation occurs, as in cold rolling or mechanical polishing. This apparently is related to preferential diffusion of chromium to the surface

where oxidation is occurring. Oxidation-reduction reactions under these conditions tend to produce chromium oxide at the expense of other oxides of lower thermodynamic stability present in the film.

Another factor promoting chromium enrichment is that of a restricted supply of oxygen if the reaction tends to be localized at partly blocked surfaces. This was pointed out by Vernon, Wormwell, and Nurse[22] in their film-compositional studies in 1944. Their films were formed on 18-8 stainless alloy polished with high-grade alumina. The film thicknesses were intermediate between Type-1 and Type-2 films. Their work indicates the dependence of film composition on polishing treatments.

Chromium enrichment does not occur for films formed under conditions where preferential diffusion or oxidation is unlikely. It should be noted, however, that lack of enrichment effects observed for chromium and nickel in ultra-thin (Type-1) films does not necessarily indicate that these elements are not important film components.

Similar data on the effect of surface treatment on oxide-film composition for Types 316 and 347 stainless steels are summarized in Table 5. The effects of iron depletion and chromium enrichment observed for Type 304 steel are also typical for Types 316 and 347 stainless steels with exceptions as previously noted. It is the redistribution of the minor elements, especially silicon and niobium (and to a lesser extent, molybdenum), which is most striking. Enrichment in all three elements is illustrated in Figure 9 for the Type-1 films. This enrichment decreases with increasing film thickness. It is less marked for surface treatments which favor the formation of Type-2 films.

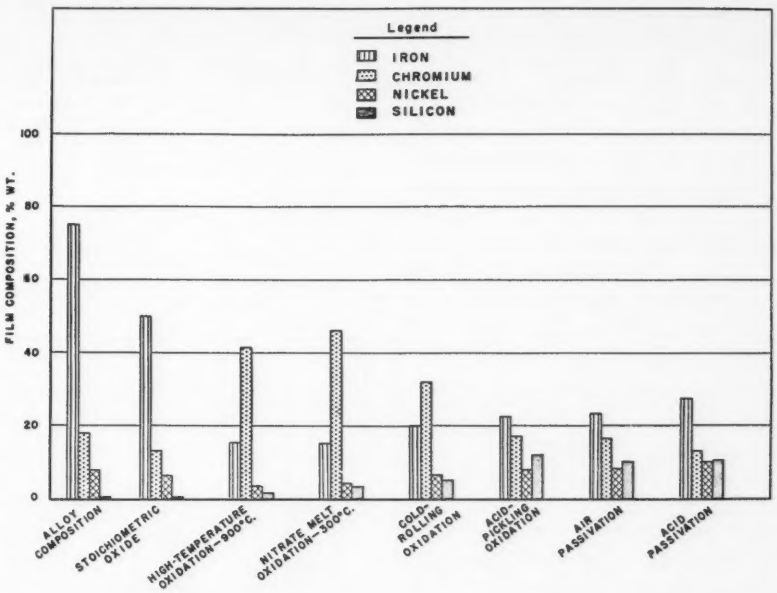

Figure 8—Effect of surface treatment on oxide film composition for Type 304 stainless steel.

TABLE 5—Effect of Surface Treatment on Film Composition[1] for Types 316 and 347 Stainless Steels[2]

Treatment	Film Thickness[3] (Å)	% Fe	% Cr	% Ni	% Si	% Nb	% Mo	AISI Alloy	Film Type
Stoichiometric	.....	45.1	12.3	9.1	0.4	...	1.6	316	Bulk
Oxidation (calc.)	.....	48.2	12.3	7.7	0.4	0.4	0.1	347	Bulk
Nitrate Melt	350 ± 50	25.2	36.1	5.2	4.0	...	1.6	316	2
Oxidation (300 C)	350 ± 50	25.0	35.2	2.2	2.0	1.2	...	347	2
Cold Rolling	150 ± 50	32.1	35.0	6.3	3.6	...	2.4	316	2
Oxidation (200 C)	150 ± 50	21.8	31.5	4.7	4.4	1.9	0.2	347	2
Acid Pickling	55 ± 15	28.8	17.2	6.6	13.5	...	4.7	316	1
Oxidation (80 C)	55 ± 15	26.7	15.2	6.7	13.6	4.2	0.3	347	1
Acid Passivation	45 ± 10	45.0	13.0	5.4	14.5	...	4.2	316	1
(60 C)	45 ± 10	44.5	20.7	8.2	12.9	5.7	0.4	347	1

[1] Values revised from reference cited in Table 4.
[2] Alloy Compositions: Type 316—17.6 Cr, 13.0 Ni, 0.60 Si, 0.08 C, 2.3 Mo, 0.77 Mn, 0.006 S, Bal. Fe; Type 347—18.2 Cr, 10.8 Ni, 0.64 Si, 0.04 C, 0.2 Mo, 0.64 Nb, 1.30 Mn, 0.009 S, Bal. Fe.
[3] Estimated values.

4. Correlation of Film Composition and Corrosion

4.1. Effect of Immersion on Film Composition

It is important to know the relationship between film properties and corrosion so that the proper interpretation of film data can be made. This effect was investigated for Type 304 stainless steel by comparing compositional data of Type-1 films for two periods of immersion in various acids under the three sets of conditions. The films were on the metal during immersion but isolated after the test for microanalysis. In the examples listed below all sample numbers refer to Table 6:

1. Passivation in boiling 5 percent H_2SO_4 followed by air exposure (Sample 1a); minor corrosion in boiling 5 percent H_2SO_4 solution for 10 minutes (Sample 1b); deposition of black residue in boiling 5 percent H_2SO_4 solution after 1 hour (Sample 1c).
2. Passivation in boiling 10 percent HNO_3 solution for 10 minutes (Sample 2a); no apparent corrosion in boiling 10 percent HNO_3 solution after 30 minutes (Sample 2b); slight attack in boiling 10 percent HNO_3 solution after 4 hours (Sample 2c).
3. Passivation in 5 percent HNO_3 — 0.5 percent $K_2Cr_2O_7$ solution at 60 C after 20 minutes (Sample 3a); scattered pitting in 10 percent $FeCl_3$ solution at 25 C after 1 hour (Sample 3b); definite pitting in 10 percent $FeCl_3$ solution after 24 hours (Sample 3c).

The compositional data for iron, chromium, nickel and silicon corresponding to these treatments are listed in Table 6. The weight loss associated with each corrosive medium shows considerable dispersion

but tends to run about 10 to 20 times greater for the "c" samples than the "b" samples.

The following general trends were observed in the film compositions as indicated by the series of bar charts in Figure 10 corresponding to the three media. The film compositions from the passive and short-term immersion samples were very similar in the 5 percent H_2SO_4 solution but the product associated with corrosion showed marked depletion in chromium and enrichment in iron. Silicon is not a significant film component in any of the samples of the No. 1 series.

The films in the 10 percent HNO_3-series show even less effect of immersion although a tendency of the film to become enriched in chromium and depleted in silicon is observed with increased times of immersion. The films in the $FeCl_3$ series also show an interesting effect of immersion time. The composition of film after short immersion was not significantly changed from that of the initial film, but the film composition after extended immersion showed appreciable enrichment in chromium as well as some depletion in iron. Sample 3c was characterized by undermining[1] of the surface, and it is possible that analytical data may be influenced by the presence of corrosion product trapped in pits for this case. The following interesting conclusions may be made:

1. The composition of the film corresponding to passivity and corrosion resistance is dependent on the medium in which the film forms.

2. The compositions of passive films are remarkably similar to those after immersion in cases where no substantial breakdown of corrosion resistance occurs.

3. The correlation of film composition before and after immersion in $FeCl_3$ solution in terms of severity of attack is striking.

[1] Effort was made to minimize error from retained corrosion product by careful washing and inspection of the test coupons for undermining effects and retained corrosion product.

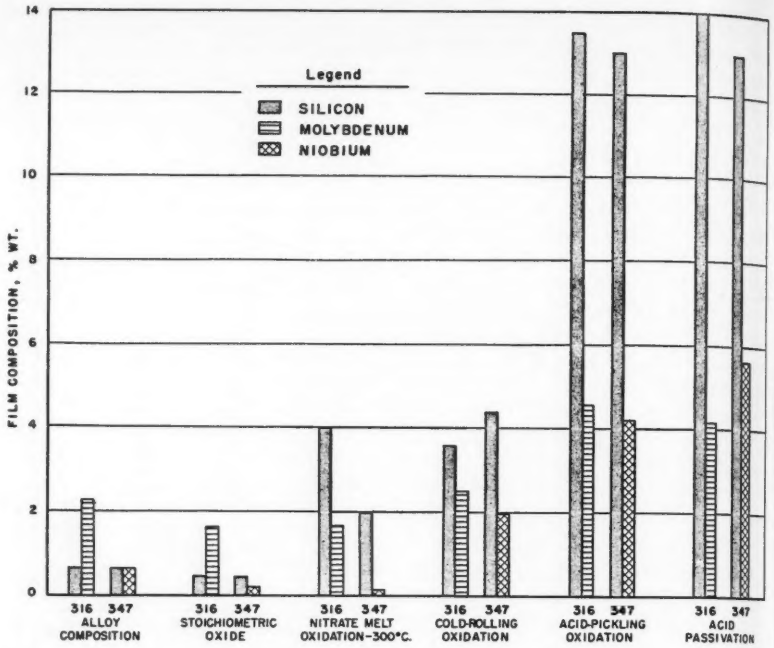

Figure 9—Effect of surface treatment on oxide film composition for Types 316 and 347 stainless steel.

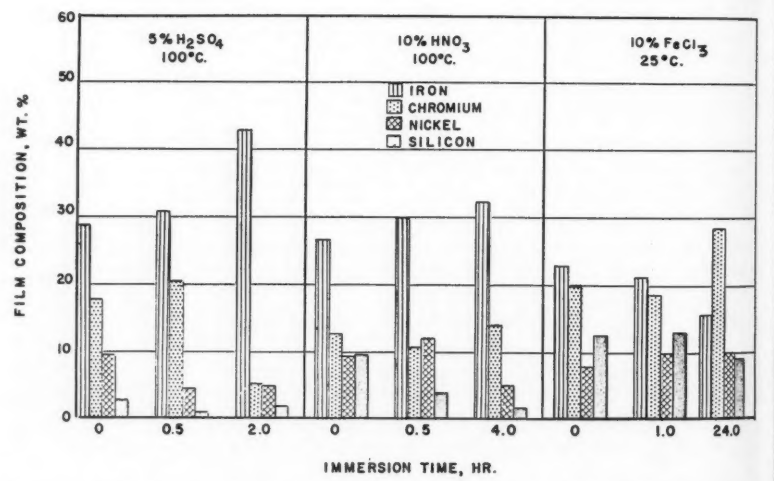

Figure 10—Effect of immersion on composition of films isolated from Type 304 stainless steel.

TABLE 6—Effect of Immersion in Corrosion Medium on Composition[1] of Oxide Films From Type 304 Stainless Steel

Sample	Treatment	% Fe	% Cr	% Ni	% Si	Appearance
1a	5 percent H_2SO_4—5 minute 100 C—air pass.	28.8	18.2	9.7	3.2	Bright Finish
1b	Immersion—10 minute	31.4	20.3	4.3	1.4	Dull Finish
1c	Immersion—60 minute	43.0	5.3	5.0	2.2	Black Residue
2a	10 percent HNO_3—10 minute 100 C—acid pass.	27.3	13.0	9.7	9.9	Bright Surface
2b	Immersion—30 minute	30.6	11.2	12.2	4.1	Cloudy Finish
2c	Immersion—4 hour	32.6	14.3	5.2	2.3	Cloudy Finish
3a	5 percent HNO_3—0.5 percent $K_2Cr_2O_7$ 60 C—20 minute—pass.	23.4	20.2	8.2	13.2	Bright Surface
3b	Immersion—10 percent $FeCl_3$ 25 C—1 hour	21.7	19.3	4.5	13.7	Minor Pitting
3c	Immersion—10 percent $FeCl_3$ 25 C—24 hour	15.9	28.9	10.5	9.4	Major Pitting

[1] Ignited film samples—water content not included.

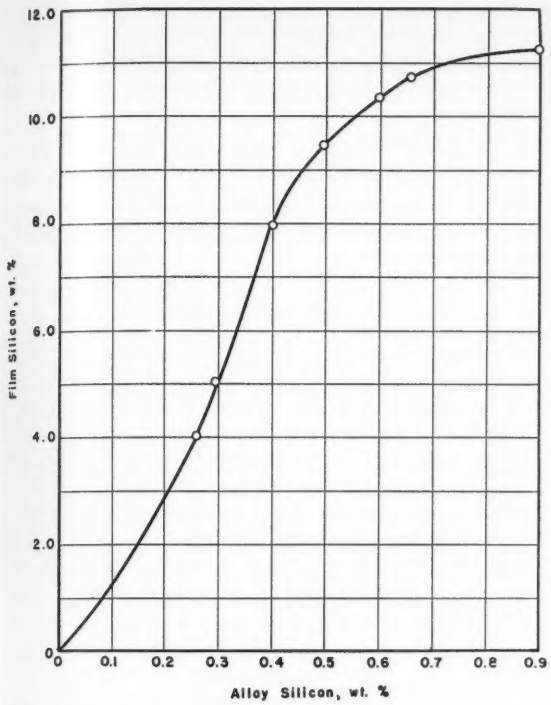

Figure 11—Effect of alloy silicon on Type-1 film silicon for Type 304 stainless steel.

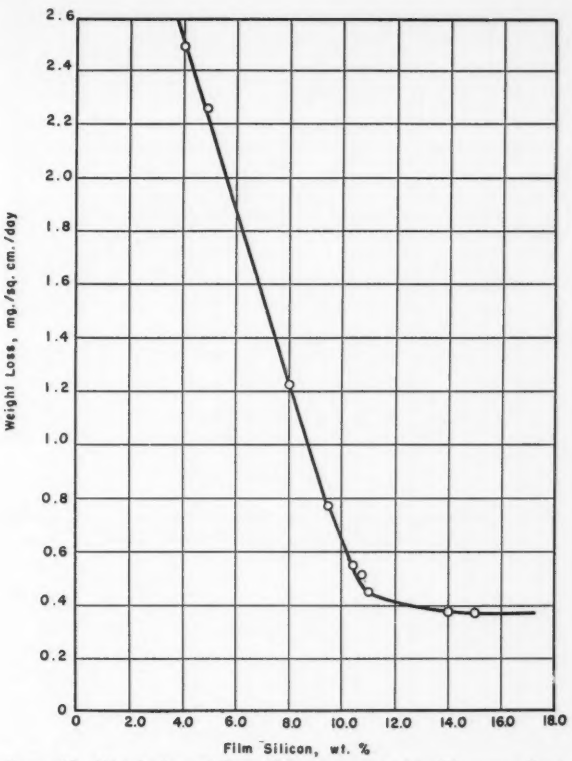

Figure 12—Weight loss of Type 304 stainless steel in 10 percent ferric chloride solution at 25 C after 24 hours.

4.2. Effect of Film Composition on Corrosion Resistance

Contrary to previous belief, Type-1 films are not necessarily characterized by significant enrichment in chromium.[19] Silicon is found to be an important component of the film on austenitic stainless alloys immersed in $FeCl_3$.[7] Composition studies indicate this effect is most striking for surface treatments and corrosive media associated with pitting corrosion.

A series of commercial heats of typical Type 304 stainless steels was passivated in 5 percent HNO_3 — 0.5 percent $K_2Cr_2O_7$ solution and tested in 10 percent $FeCl_3$ solution at 25 C for 24 hours. Their corrosion resistance, as indicated by weight loss measurements, was found to vary by a factor of 7 from the best to the poorest alloy in the series. The alloy compositions are listed in Table 1. Silicon contents of the samples were observed to vary from 0.25 to 0.90 percent by weight. The alloys were tested in groups of six coupons each (1 inch x 1 inch x ¼ inch), polished with 600 grit and given the pickling and passivation treatment previously described for the $FeCl_3$-series in Table 6. The compositions of the films formed by the pretreatment were determined and also found to be similar to those of samples 3a and 3b (Table 6).

The film silicon was found to depend on the alloy silicon as indicated in Figure 11. Silicon in the film was found to vary from 4 to 11 percent according to the silicon content of the alloy. A rapid increase in film silicon was observed as silicon in the alloy increased from 0.25 to 0.60 percent, after which the enrichment of silicon in the film increased at a much reduced rate with increasing silicon in the alloy. This inflection in the curve corresponded to approximately 10 percent silicon in the film. Weight loss data after 24 hours plotted against silicon content of the film in Figure 12 show a corresponding decrease in corrosion rate as the film silicon approaches a value of approximately 10 percent. Corresponding information on composition and corrosion rates are listed in Table 7 for comparison.

TABLE 7—Effect of Film Composition[1] on Corrosion Resistance of Type 304 Stainless Steel in 10 Percent $FeCl_3$ Solution at 25 C for 24 Hours

% Si Alloy	% Si Film	Wt. Loss (mg/sq cm)	Pit Density[2] (pits/sq cm)
0.26	4.00	2.50	1.06
0.29	5.08	2.26	0.89
0.41	7.96	1.23	0.63
0.49	9.47	0.78	0.56
0.61	10.32	0.54	....
0.66	10.74	0.51	....
0.88	11.25	0.45	0.51
1.56	14.10	0.39	0.43
1.89	15.07	0.36	....

[1] Corresponding alloy compositions listed in Table 1.
[2] Limited to pits of 10 x 10^{3} mm or greater in diameter.

It should be noted that the compositional data refer to the silicon contents of the film after passivation but before immersion. The correlation would not be significantly shifted if the film data after 1 hour immersion were used instead. If film data for samples immersed 24 hours were used for the correlation, the break in the curves would be less sharp because surface films initially poor in silicon tend to build it up during corrosion.

These films also would show a tendency to enrich

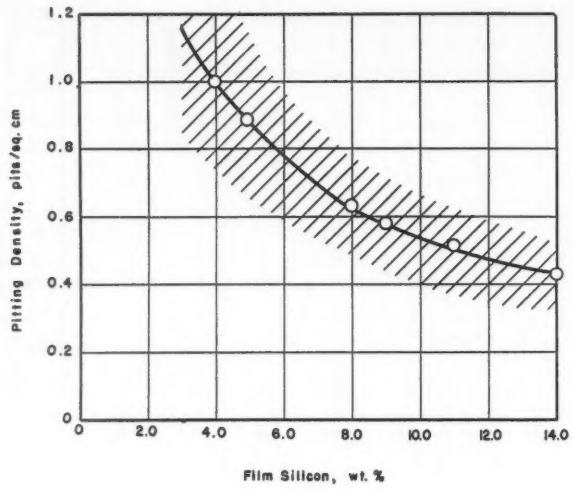

Figure 13—Pitting density of Type 304 stainless steel in 10 percent ferric chloride solution at 25 C after 24 hours.

in chromium as previously noted. In all cases, however, superior corrosion resistance is observed for alloys which tend to develop protective films enriched in silica. For these particular pretreatment and corrosion conditions the conclusions are in good agreement for either pre- or post-immersion films. The $FeCl_3$ solution was chosen on the basis of being a severe test. The results of the test are necessarily limited to the high acidity, complex formation, and oxidation-reduction reactions characteristic of this particular medium.[30]

Although most commercial Type 304 stainless steels contain at least 0.5 percent silicon, their resistance to pitting corrosion also will vary with the corrosion medium, variations in minor alloying elements, and the manner in which the surface is prepared.[31] It also should be noted that the intensity of pitting tends to increase with film-silicon as indicated by the pit density data plotted in Figure 13 for the same samples and corrosion conditions. Although the total weight loss decreases considerably as the film-silicon approaches 10 percent (all other factors constant), the corrosion is distributed over a fewer number of pits as indicated. For a variation of film-silicon from 3 to 14 percent, the weight loss decreases by a factor of 7 and the pitting intensity increases by a factor of 2.

5. Conclusions

1. Compositional studies of isolated oxide films make possible the identification of surface-active components among the large number of metallic elements normally present in stainless alloys.

2. The properties of oxide films on stainless alloys reflect the capacity of the surface to protect itself against corrosion in certain media. Oxide film properties are uniquely dependent on alloy composition, corrosive medium, and surface treatment for Types 304, 316, and 347 stainless steels.

3. Ultra-thin films associated with passivity of stainless steels are not necessarily enriched in chromium or nickel although these elements are important film constituents. In contrast, depletion in iron and enrichment in silicon is characteristic of ultra-thin films.

4. Superior resistance to weight loss of Type 304 stainless steel in 10 percent $FeCl_3$ solution at 25 C after 24 hours can be correlated with alloy compositions which tend to develop protective films enriched in silica.

6. Acknowledgments

The assistance of E. M. Mahla and N. A. Nielsen is acknowledged in connection with the electron micrographs in Figure 1 and the corrosion data in Figure 7. The data on films associated with corrosion in $FeCl_3$ solution is supplementary to a larger program of research initiated and conducted by M. A. Streicher on pitting corrosion of stainless steels at the Engineering Research Laboratory. Many of the actual film measurements were made by H. W. McGonigal and R. H. Fisher, whose assistance is also acknowledged.

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DISCUSSION

Discussion by Herbert H. Uhlig, Massachusetts Institute of Technology, Cambridge, Mass.

With regard to the role of silicon in passivity of 18-8, it is pertinent to point out that high purity 18-8[1] prepared from electrolytic iron, chromium and nickel, was as resistant and in some instances more resistant to pitting than the silicon-containing commercial alloys with which it was compared. Inasmuch as 18-8 is very low in silicon, it would seem that the major passive film does not necessarily require silicon as a component.

As we have pointed out in several publications, we believe the major passive film is an adsorbed film, usually oxygen, in the amount of about 0.27 microgram O_2/square cm of absolute surface.[2] Carbon monoxide also can adsorb on 18-8 and provide passivity in cold or hot hydrochloric acid. In my opinion, therefore, the Type-1 film discussed in the foregoing paper is not an oxide but an adsorbed film consisting in most instances of oxygen.

Reply by Thor N. Rhodin:

Surface reactions leading to film data are sensitively dependent on alloy composition, microstructure and surface treatment. With reference to film enrichment in silica, experimental data indicate clearly that improved pitting corrosion resistance is associated with this effect.

No claim is made that silicon is the only film component associated with improved corrosion resistance. Neither is the presence of film silica predicted to be a necessary and sufficient characteristic of all passive films. This happened to be the case, however, for the alloy compositions and testing conditions of this study for Types 304, 316, and 347 stainless steels.

Commercial alloys having film enrichment in silica were found to possess superior pitting corrosion resistance to those in which silica enrichment did not occur. By this token the corrosion resistance of your special alloys might have been improved considerably by addition of small quantities of silicon. The fact that the corrosion resistance was as good as you report, can, in this case, be easily attributed to factors other than film-silica.

One must be careful to make interpretations within the experimental framework of the study for the surface treatments and precise alloy compositions described in this paper (see Table 1). Comparison between special experimental alloys and commercial material can be very misleading.

For example, the special melts referred to by you are in the carbon range 0.005-0.013 percent as compared to 0.050-0.090 percent for the commercial alloys of the film study. Comparison is obscured further by the high nitrogen contents of your experimental austenitic alloys (0.165-0.240 percent). Variation of carbon and nitrogen alloy-contents in this range might have considerable influence on Type-1 oxide films. Failing to take into account these variables makes comparisons between film enrichment and corrosion resistance uncertain.

In addition to this, influence of heat treatment, microstructure and impurity control can invalidate comparisons between experimental ferritic heats and commercial austenitic heats of stainless alloys. Comparison of pitting corrosion data for different surface treatments and different testing conditions must be examined critically because of the great fluctuation particularly characteristic of this type of corrosion.

A four-hour "drop" test on pickled surfaces would not be expected to give corrosion rates comparable to 24-hour "immersion" tests on the passivated surfaces used in this study. The observation may be made that a valid evaluation of the contribution of silicon to the pitting corrosion resistance of the special alloys can be achieved only by careful reproduction of the alloy compositions and testing procedures.

With reference to the role of oxygen in defining passivity of stainless steels, precise data on the nature and extent of oxygen adsorption on deoxidized stainless steel surfaces as a function of temperature have not been reported as yet in the literature.

[1] H. H. Uhlig. Trans. *Am. Soc. Metals*, **30**, 947 (1942).
[2] H. H. Uhlig and S. S. Lord, Jr. *J. Electrochem. Soc.*, **100**, 216 (1953).

Any discussions of this article not published above will appear in the June, 1956 issue

Methods of Preventing Corrosion in Sewerage Systems*

By ERVIN SPINDEL*

Abstract

Means of preventing deterioration of structures handling sewage or exposed to the fumes from sewage are discussed. Relative merits and application techniques of chemical additives are considered. Recommendations concerning control through design to increase velocity or eliminate vapor space are weighed. Application of and results achieved through ventilation of sewers are reported in some detail, including service results on installations over periods up to 16 years.

Control through use of materials resistant to the corrosives in sewage is outlined. Special cements, clay and plastic liners, special jointing materials and protective coatings for metallic and non-metallic materials at treatment plants are mentioned. Cathodic protection as an effective control measure is considered and recommended where feasible.

Introduction

CORROSION MAY EXIST in many different forms in sewers and in treatment plants. Determining which of the available methods of corrosion control will be used in a given instance is dependent on such factors as type of material to be protected, climatic conditions, and economic considerations. It is the purpose of this paper to outline briefly some of methods in use at this time.

Corrosion and deterioration of sewers result generally from two major causes: (1) The chemical action of sulfides and sulfates in the sewage and in the ground water infiltrating into the sewer, and (2) Electrolytic action.

In the case of chemical action, corrosion can be prevented either by curtailing the formation of the corrosive compounds or by protecting the material from the action of gases and other harmful elements.

Chemical Additives

One of the most widely used methods of curtailing the generation of sulfides in sewers is by the use of chemical additives. The addition of oxygen, which prevents breaking down of sulfates to sulfides, is one method. Oxygen can be added by means of blowing air into the sewer (see material under heading of "Ventilation"). A more costly method is by the addition of nitrates.[1]

Chlorination of sewage at points close to its origin, which results in partial disinfection, has been successful in reducing sulfide generation by suppressing the activity of bacteria in the sewers. As little as 2 ppm and as much as 12 ppm of chlorine have been required, depending on the period of travel to plant and temperature of sewage. In some cases, 2-point application has been used for higher efficiency and chlorine economy. A dosage of 5 ppm has proven effective in most cases. Prechlorination in treatment plants with from 2 to 20 ppm chlorine added serves the dual purpose of disinfection and odor control.[2]

Addition of metallic salts, such as iron chloride, to sewage converts soluble sulfides into fixed sulfides. This method of treatment is relatively inexpensive. Iron chloride may be applied at any point in the sewer and is used up only as hydrogen sulfide is produced. Any surplus iron travels along with the sewage, without being depreciated by the organic matter, remaining available as needed between the point of application and the treatment plant. This method is known as the Scott-Darcey Process.[2] It was introduced in Oklahoma City by L. A. Scott, Superintendent of Water and Sewage Treatment, and H. J. Darcey, Chief Engineer of the Oklahoma State Department of Health.

Various sulfates also have been used to react with dissolved sulfides, as have chlorinated hydrocarbons. An example of the latter is orthodichlorobenzene (known commercially as Chloroben.[3]) The City of Long Beach[4] and the City of Oklahoma City have reported quite satisfactory results from Chloroben, using a dosage of about 1 ppm. The City of Los Angeles has made extensive experiments in the use of this method.[5] At first it appeared that this material would prove extremely satisfactory in the control of sulfides; however, later experiments made by Richard Pomeroy, Consulting Engineer of Pasadena, California, do not show any effective reduction of sulfides by the use of Chloroben. These results also were borne out by report of C. W. Beardsley of the Bureau of Standards, City of Los Angeles.

Design of System

It would appear that in large systems, such as in the City of Los Angeles, the use of chemical additives is prohibitively expensive. Pomeroy and Bowlus[6] in their progress report on sulfide research, advanced the idea that the sulfide generation could be curtailed by properly designing the sewerage system to provide adequate velocity of flow in correlation with biochemical oxygen demand and sewage temperature. Tests made by the Bureau of Engineering of the City of Los Angeles, however, have not borne out this theory. Because the design of the sewerage system must necessarily follow the terrain (thereby affecting the velocity of the sewage) such a method of sulfide control becomes impractical. Another theory advanced to prevent the attack of sewers by sulfides involves complete submergence. Under this system the sewers would be kept running full at all times. It is true that surfaces which are permanently immersed will not be attacked by sulfides but the plan itself is impra-

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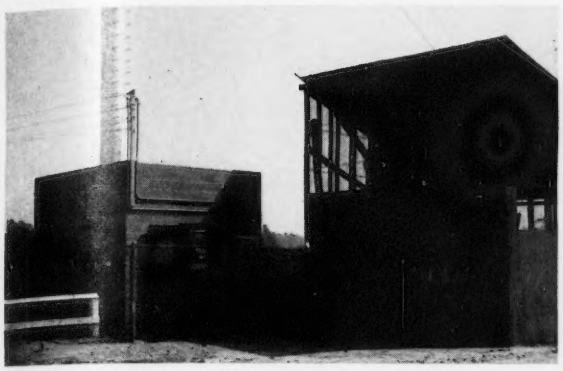

Figure 1—A typical ventilation station on the Los Angeles Outfall System.

tical from an operational standpoint. The wide daily variation in quantity of sewage flow and the necessity for providing capacity for anticipated future increases in flow causes periods of extremely low velocities, resulting in sedimentation in the sewers. In addition, generation of sulfides can be expected in completely filled lines, causing release of hydrogen sulfide at the treatment plant.

Ventilation

Ventilation of sewers, as mentioned previously, supplies oxygen to the sewage. This prevents the breaking down of sulfates to sulfides by satisfying the oxygen hunger of certain bacteria. The major function of ventilation, however, is to dry the walls of the sewers.

Ventilation by forced draft (using blowers which force air into the sewer) has been used for quite some time in Melbourne, Australia. This method can be used there because of the isolated location of the sewers.

The most extensive use of ventilation of sewers in the United States has been by the City of Los Angeles. The procedure there involves using the method of evacuation of air from the sewer by means of a blower at one point. When this system is used, fresh air is admitted at intervals along the sewer.

The first experimental ventilating station was built in 1938 on the Los Angeles North Outfall Sewer. That sewer was built of concrete, had a 10-foot 6-inch high by 12-foot 3-inch wide semi-elliptical cross-section and was lined with clay liner blocks above the spring line. The joints between the liner blocks were kept as narrow as possible and filled with cement mortar. The lower six-mile portion of the sewer was sealed from the rest of the system by an inverted siphon under the Centinela Valley. This completely obstructed the flow of air from the rest of the outfall system into this lower portion. It might be pointed out that no air was admitted to this portion of the sewer from 1924 to 1936. An inspection in 1936 by Reuben F. Brown, Assistant Superintendent of Sewers, showed only 11 percent oxygen in the atmosphere and great deterioration of the sewer due to sulfide action. In many places tile was off and the concrete was soft and porous. The joints between tiles had been reduced to mushy

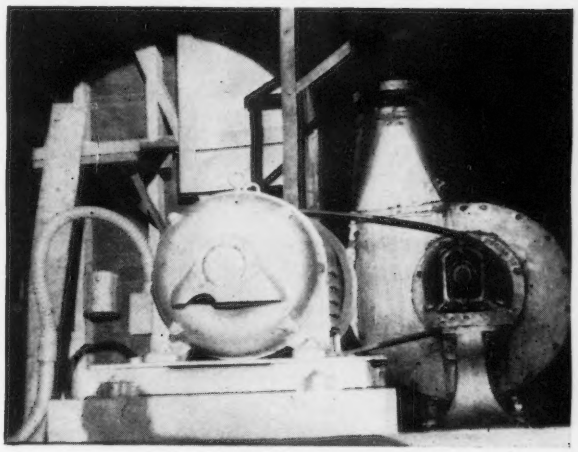

Figure 2—Ventilating fan and motor.

gypsum. To correct this condition, the ventilation station was built about 2,000 feet downstream from the Centinela Siphon (see report by E. G. Studley,[7] now Principal Engineer, Sewer Design Division).

Immediate improvement was reported upon the start of ventilation. Holes for admitting air were opened successively farther away from the fan, until about 14,000 feet of sewer was being ventilated less than a year after the fan was first put in operation. Before ventilation had been started, there were stringy growths on the sides of this sewer and the inner surfaces were extremely moist with drops of water gathering and running down the sides. As ventilation dried the sewer, the surface deposits dried out and disappeared, giving the sewer a fairly new appearance. The exhaust air from the ventilation station averaged 16 ppm hydrogen sulfide. The amount of sulfides in the sewer, was reduced 80 percent by ventilation. This experimental ventilation station was shut down in August, 1941. (See Figures 1 and 2 for views of a typical ventilation station.)

The success of this experiment led to the building of a permanent ventilation station approximately half way between the Centinela Siphon and the Hyperion screening plant. This station was put into service in November 1942 and has since been reconstructed. This reconstruction was completed in 1953 after a period of about two years of inoperation. Additional ventilation capacity for this lower stretch of the North Outfall Sewer was added upon the completion of the Hyperion Treatment Plant. (This was done because the fans at the plant draw air from the lower portion of the North Outfall Sewer.) The condition of the North Outfall Sewer between the Centinela Siphon and the Hyperion Treatment Plant has remained essentially the same since 1938, when the ventilation was started. No further deterioration of the sewer has been reported in this stretch for 16 years.

The Hyperion Treatment Plant has also provided ventilation for the Central Outfall Sewer. This sewer which had originally been constructed in 1906, was renovated and was put back in service in 1951. The ventilated section of the Central Outfall Sewer ex-

Figure 3—Sewer lined with clay liner at an extremely gaseous intersection on Los Angeles North Outfall Sewer. The sewer itself is more than 30 years old.

tends from Hyperion to Slauson and Van Ness Avenues, a distance of approximately eight miles.

Another example of the effectiveness of sewer ventilation is the sewer serving Relief Sewer District No. 5. This large unlined concrete sewer was put into service in Los Angeles a few years ago. Incipient deterioration had been reported in the sewer, and an air connection to the Central Outfall Sewer was provided. This flow of air, which was being pulled from the fans at Hyperion, effectively halted the deterioration of this sewer during the period when full ventilation was being supplied. This extended to 10 miles, the distance that the fans at Hyperion were pulling air through the sewer.

Protective Materials

From the standpoint of economics, it is usually sound practice to avoid periodic expenditures resulting from the use of chemical additives or ventilation. It generally is better to spend more money in the first cost of construction in order to make the materials of construction impervious to the action of corrosive chemicals in sewage. In so far as small sewers are concerned, this is accomplished by the use of vitrified clay pipe; large sewers and structures, however, must be constructed of concrete or steel and therefore must be protected.

A large number of laboratory experiments have been conducted to develop a concrete which would have a high resistance to sulfate attack. Use of Portland cements (such as ASTM Type V) which are low in tri-calcium aluminate, increases the resistance to sulfate attack. It has been found that the use of finely divided pozzolan as a replacement for about 25 percent of the Portland cement, and the use of an air entraining or wetting agent still further improves the sulfate resisting quality of the concrete. All this has negligible effect, however, upon the ability to resist action of sulfides.

Both protective coatings and protective linings have been used to help materials resist the action of sulfides. Once a sewer pipe has been put in service it is extremely difficult to go back and make repairs. For this reason the City of Los Angeles uses on sewers only protective linings which will have long

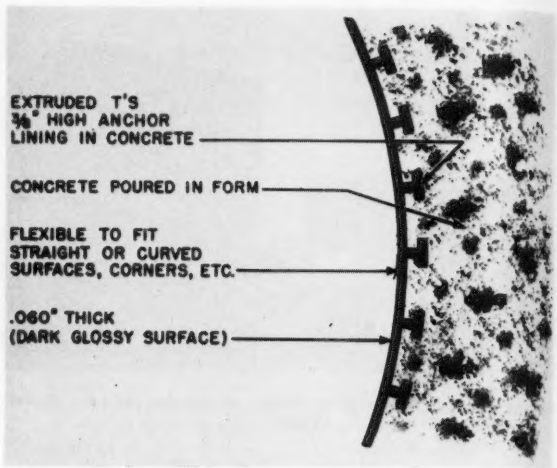

Figure 4—Typical cross section detail of plastic liner plate.

life. The two types of linings in use by the City of Los Angeles are clay liner block and vinyl plastic liner plate.

Clay Liner Blocks

Clay liner blocks are generally about 9½ inches by 18 inches or 24 inches long with three longitudinal lugs on the back which are imbedded in the concrete. The blocks themselves have been proven by laboratory tests and actual installation to be sulfide resistant.

There are many miles of sewer in the Los Angeles System, which are lined with clay liner block and which are in excellent condition after more than 20 years service (see Figure 3). In the past, however, material used in filling the joints between the tiles has been vulnerable to attack by sulfides. The North Outfall Sewer was built in 1924 with clay liner block, with cement mortar as filler between the joints. In some places joint material had been eaten away. As a result of this the sulfuric acid reacted with the concrete behind the liner blocks, causing the concrete to expand and pop off the clay block at the lugs. It was obvious that the clay block, itself, had not been attacked; this posed, however, a serious condition at several points. Present specifications call for either synthetic rubber base joint compound or bituminous sewer joint compound (hot poured) in the joints between the tiles. A lining of this type is now being used in a 1½ mile section of the La Cienega-San Fernando Valley Relief Sewer.

Plastic Liner Plate

The plastic liner plate, according to the Los Angeles specification, is a combination of inert synthetic resins, pigments and plasticizers in flexible sheets approximately .060-inch thick. The sheets are chemically inert and resistant to action of acids, such as sulfuric and nitric, alkalis and sulfates. Integrally molded "T"-extensions of the same composition as the liner hold the plates firmly in place when imbedded in the concrete. (See Figure 4.)

Plastic liner plate has been in use a relatively short time, so only rough estimates of its life can

be made. Extensive tests and conditions of existing installations would seem to indicate, however, that the life would be at least 50 years, possibly much longer. In this connection many laboratory tests have been conducted, both by the manufacturer and the City of Los Angeles. In 1937, specimens of vinyl chloride plastic mortar were placed in the outlet of the Centinela Siphon of the North Outfall Sewer. On an inspection by members of the Bureau of Engineering and Bureau of Standards of the City of Los Angeles in 1949, 12 years later, no deterioration was found in any of the samples.

The City of San Diego in 1947 installed plastic liner plate on a structure under highly corrosive conditions. Constant inspections have been made on this installation and show no evidence of deterioration, surface breaking or brittleness.

This same condition is found on some of the more recently built installations in the Los Angeles area. A tank used at the Hyperion Treatment Plant for storage of concentrated ferric chloride has this type of liner plate; the tank has been in constant use since 1950 and is in excellent condition at the present time. Plastic lining is used also on the 8-mile long Magnolia Trunk Sewer in Orange County. The City of Los Angeles put a plastic lining in the 60-inch diameter West Los Angeles Interceptor (see Figure 5). This 7-year-old sewer shows no evidences of corrosion. Another place where plastic liner plate is being used is in the 10½ mile long La Cienega-San Fernando Valley Relief Sewer, now under construction. All but a 1½ mile length of this sewer is lined with plastic liner plate.

Coatings and Paints

In structures such as treatment plants and pumping plants, concrete and metal surfaces come into contact with sewage or corrosive atmosphere. Coatings have been used for protection from corrosion in a great many such structures. But coatings or paints may be used only on structures which can be taken out of service for periodic recoating or repainting.

For painting metal surfaces, zinc chromate primer has been found more satisfactory than red lead. In surfaces that come in contact with sewage, good grade bituminous paints have proven most satisfactory. For surfaces above liquid level, titanium dioxide-zinc oxide fume-proof enamel is effective, provided a good primer coat has been applied.[8] Most authorities agree that surface preparations, which range from wire brush to sandblasting or flame cleaning, is just as important a consideration as the type of paint employed.

On concrete surfaces exposed to sewer gas or sewage, bituminous base coatings (both coal tar pitch and asphaltic) have been used successfully in many installations and are probably the most widely used of the protective coatings. Hot applied bituminous coatings have been found to be superior to cold applied compounds; they are, however, more expensive and more difficult to apply. Chlorinated rubber base paints, show good resistance to acids and alkalis, but are unstable above 140 F. Other types of coatings in use are vinyl resin compounds, which seem to resist the action of sulfides satisfactorily and micro-crystalline wax. The latter material is a powder which is applied by flame spraying onto a dry clean surface.

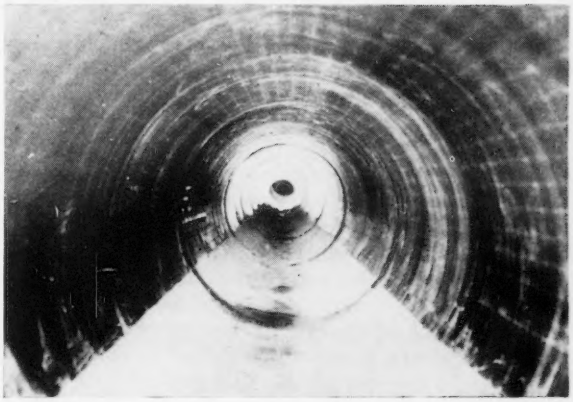

Figure 5—Five-foot diameter sanitary sewer on West Los Angeles Interceptor. Note the plastic liner on top three-quarters of circumference.

The Department of Public Works of the City of Los Angeles, through its Bureaus of Engineering, Standards and Sanitation, has for many years conducted a program of testing the many commercial brands of protective coatings. It is not the policy of the Bureau of Engineering to specify any material unless it has been tested by the Bureau of Standards. Coatings are tested for resistance to hydrogen sulfide by applying them to concrete and steel plaques and exposing them to the action of hydrogen sulfide. This is done by hanging the plaques in a sewer structure in which there is very high concentration of gas. Periodic checks are made of the condition of the samples which remain exposed until failure.

Cathodic Protection

In the preceding paragraphs the control of chemical deterioration in the sewerage system has been discussed in detail. It should be pointed out that the problem of galvanic or electrolytic corrosion, as found in the mechanical equipment of a sewage treatment plant is also quite serious. The preventive methods being utilized in sewage works are usually one or a combination of the following procedures:

1. Use of protective coatings.
2. Use of metal and alloys which resist the environment encountered.
3. Chemical treatment of the sewage to make it less aggressive.
4. Cathodic protection.

Flow of protective current for cathodic protection may be supplied in one of two methods. One is by using a metal plate whose solution potential in a particular corrosion environment is more anodic than the metal to be protected. Metals such as zinc, cadmium, magnesium and aluminum have been used as sacrificial metals in combination with iron or steel. The second method makes use of an external current source and auxiliary anode. This is the most commonly used method.[9]

When compared with other methods of corrosion

control, properly applied, tested and adjusted cathodic protection has many advantages which justify its use in combatting corrosion. In many cases installation can be made without taking the equipment to be protected out of service. Surfaces to be protected do not require special preparation. Old paint films and scale and corrosion products actually reduce current density requirements for complete protection. This eliminates the necessity for laborious cleaning, such as sandblasting, of the surfaces to be protected. The accelerated corrosion which frequently occurs at certain points with development of failure of protective coatings is not encountered when an adequate current density is supplied to take care of the cathodic process on the surfaces exposed to the corroding media. In addition to this, cathodic protection requires very little maintenance and supervisory attention. Its use can be economically justified when compared with other methods of underwater corrosion control.

At present there are no definite criteria for setting up current density requirements for cathodic protection. This current density requirement has been reported to range from .3 to 60 milliamperes per square foot for the protection of iron. Studies have shown that current density requirements will increase with increased dissolved oxygen concentration of the corroding liquid; studies also show that stirring the corroding liquid will increase the required current.

It might be pointed out that excessive current density will not be harmful to iron, but will be injurious to metals such as aluminum. The possibility, however, of deleterious effects resulting from *properly designed* cathodic protection is negligible.

A design consideration that must be made in any installation is the provision for a continuous lower resistant path back to the source of power from all submerged surfaces receiving a protective current flow. The importance of this is illustrated by the corrosion induced on a poorly bonded pipe joint when current is flowing through the pipe. A portion of the current will leave the pipe and flow through the electrolyte to the adjoining pipe section around the resistance at the joint. Corrosion attack is induced at the pipe joint where the current enters the electrolyte, whereas the adjoining pipe section receiving the same current flow from the electrolyte is being protected.

Conclusion

In conclusion it should be pointed out that the methods of controlling corrosion in a sewerage system which have been outlined in this paper barely scratch the surface of this complex subject. Seven methods of control have been mentioned: chemical additives, velocity-B.O.D.-temperature correlation, submersion, ventilation, protective linings, protective coatings, and cathodic protection. There are many other phases of this matter which have not been mentioned, and new developments are constantly being brought out by research and experiment. The battle against corrosion is going on and will continue to go on with increasingly favorable results.

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Any discussions of this article not published above will appear in the June, 1956 issue

ERRATUM

Inhibition of Metallic Corrosion in Aqueous Media
by Harry C. Gatos. Corrosion, Vol. 12, No. 1, 23t-32t (1956) Jan.

Page 28t, column 2, third and fourth lines of fourth paragraph should read:

types of inhibitors. For that reason no particular importance should be

Publication 56-2

A Bibliography of Corrosion by Chlorine

A Report of Technical Unit Committee T-5A on Corrosion in the Chemical Manufacturing Industry (Compiled by Task Group T-5A-4 on Chlorine)*

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* R. I. Zimmerer, Petro-Tex Chemical Corporation, Houston, Texas, chairman.

Abstract

This report contains 86 abstracts of papers on corrosion by chlorine. It is indexed by materials and coded by the NACE Abstract Code.

Introduction

MEMBERS OF Task Group T-5A-4 on Chlorine have spent considerable time compiling this bibliography. It is fitting that this completed work should be a tribute to their effort.

Abstracts of Chlorine Corrosion Literature

No. Abstract

1 **Chlorine Gas and Molten Aluminum Resisted by Ceramic Coating.**[1] *Chem. Proc.*, **16,** No. 9, 148-159 (1953) Sept.

Describes porcelain enamel steel pipe. —BTR.

2 **Large Pennsalt West Coast Unit Opens in Oregon.** *Chem. Eng.*, **54,** No. 8, 182-184 (1947) August.

Chlorine gas from Gibbs cells conducted to chlorine liquefication building by 18-inch diameter ceramic pipe. Gas cooled in spray type ceramic coolers to 60 F to remove all moisture possible before entering drying towers where sulfuric acid removes last traces of moisture.

Gas compressed to 25 psi by Nash Hytor compressor. Gas cooled in two stages to —45 F, and resulting liquid chlorine flows into storage tanks to be loaded by means of pressure differential into 100- and 150-pound cylinders, 1-ton cylinders and tank cars.

3 **Materials Engineering File Facts—Corrosion Resistance of Titanium Metal in a Number of Chemical Reagents.**[2] *Materials & Methods*, **32,** No. 1, 75 (1950) July.

Table of effects of chemical reagents. Includes organic and inorganic acids, and other well known chemicals. INCO.

4 **New Chlorine—Caustic Plant for the Southwest.** *Chemical Industries*, **63,** No. 6. p. 956-959 (1948) December.

Describes electrolytic chlorine plant of major chemical manufacturer.

Glass used for entrance headers to cells and chlorine exit piping.

Wet chlorine from cells passes through two enclosed glass coolers which reduce temperature to 60-70 F. Cooled gas is dried in three ceramic plate drying towers and three cast iron towers.

Chlorine liquefied by cooling to —20 F by three refrigerating units incorporating centrifugal compressors. This method eliminates maintenance problems with the reciprocating compressors, coolants and refrigerant handling equipment which are normally required.

5 **Silver in Chemical Plant.**[3] *Metal Ind.* (London), **79,** No. 11, 223 (1951) Sept. 14.

Silver, one of the most important corrosion-resistant metals, withstands the action of virtually all the organic acids and of many mineral acids and salts. It can be used in the presence of halogens and their compounds and is unaffected by alkalies. Silver-lined mild steel equipment is now available to the British chemical industry combining high strength and corrosion resistance. Table is included.—INCO.

6 **Tubing Resists Corrosion.**[4] *Steel.* **128,** No. 10, 86 (1951) Mar. 5.

Tubing and pipe to handle a variety of oxidizing and reducing corrodents is being produced. Designated as Carpenter alloys B and C, they are made from strip of the Hastelloy analyses made by Haynes Stellite Division, Union Carbide & Carbon Corporation. Alloy B is characterized by its effective resistance to hydrochloric acid in all concentrations and at all temperatures including boiling. It is also recommended for sulfuric acid at temperatures above 80 C but is not recommended for oxidizing atmospheres. Because of its chromium content, alloy C will withstand strong oxidizing conditions such as those encountered with nitric acid, free chlorine, aqueous solutions of chlorine and acid solutions of ferric and cupric salts. The alloy will also resist phosphoric acid and is highly resistant to acetic, formic and sulfuric acids. Tubing and pipe made of alloy C are generally recommended for use with hydrochloric acid up to 50 C. Available sizes are given. Manufactured by Carpenter Steel Co.

—INCO.

No. *Abstract*

7 **Uncorrodible Metal.**[5] *Steel*, **124,** No. 18, 81 (1949) May 2.

Titanium metal is practically unaffected by exposure to sea water or marine atmosphere according to test data obtained by Remington Arms Co., Inc., Bridgeport, Conn. Tests indicated that none of the standard metals approached the corrosion resistant properties of titanium, and that wet chlorine gas, hot chromic acid and hot ferric chloride solutions are not corrosive to it.—ALL.

8 **Corrosion Resistance of Copper and Copper Alloys.** AMERICAN BRASS CO. *Chem. Eng.*, **58,** No. 1, pp. 108-112 (1951).

Copper and copper alloys are not attacked by dry chlorine gas at room temperature or lower. Moist chlorine gas is corrosive to all copper alloys.

9 **Corrosion Resistance of Copper-Magnesium Alloys in Chlorine, Hydrogen Sulfide and Sulfur Dioxide.** W. BANKLOH and W. G. KRYSKE. *Chem. Abstracts*, **34,** 5813-9 (1940); *Metallwirtschaft*, **19,** 157-160 (1940).

Eleven copper-magnesium alloys in form of castings, varying in composition over the whole range of the copper-magnesium diagram were exposed to chlorine, sulfur dioxide and hydrogen sulfide gases at room temperature, at 400 and 700 C, and the changes in weight were observed. The extent of attack was directly proportional to the time of exposure. The reaction products had no passifying effect. The effect of chlorine could be measured only at room temperature owing to the intensity of reaction at higher temperatures. The magnesium-rich alloys showed particular resistance to hydrogen sulfide, while the copper-rich alloys were more resistant against sulfur dioxide.

10 **Chlorine Bleaching.**[6] E. R. BARKER, JR., HOLLINGSWORTH AND WHITNEY. *Paper Trade J.*, **135,** No. 20, 253-254, 256-257 (1952) Nov. 14.

In handling dry chlorine, drums and tank cars are made of steel. Valves are of bronze, or steel with Monel stems. Hastelloy C is used for valve trim. Steel pipe is used in all dry phases of the liquid and gas handling. When handling wet chlorine, Hastelloy C is used and high silicon cast irons have also been adopted. Several plastic materials have been developed that show great promise. Stainless steels are useful for low concentrations of chlorine but are apt to be rapidly attacked under some conditions.—INCO.

11 **The Action of Chlorine on Refractory Materials.** I. Preliminary Experiments with Some Typical Commercial Products. L. R. BARRETT, F. H. CLEWS AND A. T. GREEN. *Chem. Abstracts*, **35,** 4168-7 (1941). Gas Research Board, Copyright Publication No. 2, 93-96 (1940).

Exposure to chlorine for two hours at 1000 C caused greatest loss in a plumbago brick, carbon dioxide and silicon tetrachloride being formed. The blue-clay brick was attacked markedly and silicone dioxide, sillimanite and aluminous firebricks slightly owing to the formation of volatile chlorides of iron, magnesium, calcium and aluminum.

12 **The Action of Chlorine on Refractory Materials.** III. A Note on the Action of Chlorine on Diatomaceous Earth. L. R. BARRETT, H. M. RICHARDSON AND A. T. GREEN. *Chem. Abstracts*, **35,** 4168-9 (1941). Gas Research Board, Copyright Publication No. 2, 104 (1940).

The refractoriness of a diatomaceous insulating material was increased from cone 17 to 27 by treatment for 10 hours with chlorine at 1000 C.

13 **Avoiding Enamel Difficulties Through Proper Furnace Operation.** I. M. BOZSIN. *Chem. Abstracts*, **44,** 8081e (1950); *Finish*, **7,** No. 5, 25-7, 78 (1950).

A discussion of the effect of harmful gases. Three percent water causes orange peel; sulfur trioxide or silicon tetrafluoride produces scumming, and chlorine causes bleeding and copper-heading. II. *Ibid.* No. 6, 22-24, 56. A discussion of combustion control.

14 **Mechanical Engineering the Chemical Industry.** F. H. BRAMWELL. *Inst. Mach. Eng.*, Advance Copy, (1949) May, 8 pp.

This paper deals with materials of construction for chemical plants, pumps and compressors, containers, etc.; it is confined to industries established on Merseyside: sulfuric acid, chlorine, caustic soda and bleaching powder production. An abridged version is published in *Engineering*, **167,** 597-600 (1949) June 24.

15 **Corrosion by Chlorine and by Hydrogen Chloride at High Temperature.**[7] M. H. BROWN, W. B. DELONG AND J. R. AULD. *Ind. Eng. Chem.*, **39,** 839-44, (1947) July.

A number of common engineering materials were exposed to dry hydrogen chloride and to dry chlorine at elevated temperatures in short time tests carried out to determine the relative corrosion resistance and limiting temperatures of serviceability of these materials. Nickel and the high nickel alloys were indicated to be most useful under these conditions. Platinum and gold were found to be resistant to a higher temperature than nickel in dry hydrogen chloride but not in dry chlorine. For some materials the effect on corrosion of dilution of these gases with air, sulfur trioxide, or water vapor also was investigated.

16 **Chlorine-resistant Vitreous (Siliceous) Materials in the Preparation of Aluminum Chloride.** P. P. BUDNIKOV. *Chem. Abstracts*, **28,** 4182-9 (1934); *J. Applied Chem.* (USSR), **6,** 1043-1048 (1933).

The best temperature for the preparation of aluminum chloride from $Al_2O_3.2SiO_2$ plus carbon monoxide plus chlorine is 1000-1150 C. Suitable lining for the apparatus is a high-grade Dinas brick prepared from quartzite containing silicon dioxide 97.12-98.88, aluminum oxide 0.41-1.47, ferric oxide 0.62-1.3, calcium oxide 0.1-1.08, magnesium oxide traces to 0.17, with calcium oxide 1.5-2.0 percent as binder. The best mortar should contain a mixture of quartz 60, waste from burned Dinas brick 30, and a plastic refractory clay 10 percent. The seams should not exceed 3 millimeters, so as to avoid the escape of gases.

17 **Wet and Dry Chlorine vs. Materials of Chemical Plant Construction.**[8] H. M. CHURCH, J. L. TRAUB AND J. S. CHOWNING. *Chem. Eng.*, **54,** No. 1, 211-214 (1947).

Lead—recommended for service with wet chlorine gas at temperatures up to 230 F. High-silicon irons—good resistance to wet chlorine gas at lower temperatures. Chemical porcelain—used in handling hot, wet cell gas. Can be used at temperatures up to 250 F if thermal shock is avoided.

18 **The Action of Chlorine on Refractory Materials.** II. Experiments on the Action of Chlorine on Certain Oxides, Silicates and Spinels. F. H. CLEWS, H. M. RICHARDSON AND A. T. GREEN. *Chem. Abstracts*, **35,** 4168-8 (1941). Gas Research Board, Copyright Pub. No. 2, 96-104 (1940).

In the absence of carbon, the approximate order (declining) of reactivity to chlorine at 1000 C was iron oxide, magnesium oxide and silicon dioxide, titanium dioxide, zirconium dioxide, aluminum oxide. More complex compounds containing these oxides, such as silicates and spinels, are less reactive than the free constituent oxides. The rate of reaction depends on the thermal history, being less for strongly calcined materials.

19 **Wet and Dry Chlorine vs. Material of Chemical Plant Construction**[9] (in three parts), CORROSION FORUM (Editor: E. C. FETTER), *Chem. Eng.*, **54,** No. 1, 211; **54,** No. 2, 219; and **54,** No. 3, 213 (1947).

A qualitative discussion of materials of construction for chlorine service covering the lead, high silicon iron, porcelain, silica, Worthite, tantalum, rubbers, glass, carbon-graphite, Hastelloy, wood, Durimet-Durichlor, nickel, monel and stoneware.

20 **Acetic Acid and Chlorine vs. Materials of Chemical Plant Construction.** CORROSION FORUM (EDITOR: E. C. FETTER). *Chem. Eng.*, **54,** No. 5 241-242 (1947) May.

Discusses resistance of Haveg, stainless steels, and organic coatings to wet and dry chlorine.

Haveg: adaptable to wet or dry chlorine. Used as duct work and cell headers for 15 continuous years. Not recommended in drying operations with above 50 percent sulfuric acid. Stainless Steel: Rapid attack by wet chlorine. Severe attack at 800-900 F with dry chlorine. Protective Coatings: Resistance of most organic coatings said to be usually poor (in 1947).

21 **Titanium: Good But Not Miraculous.**[10] CORROSION FORUM (EDITOR: E. C. FETTER). *Chem. Eng.*, **57,** No. 5, 263-264 (1950) May.

The corrosion resistance of titanium and stainless steel are compared in re-

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spect to sulfuric acid, hydrofluoric acid, nitric acid, hydrochloric acid, chlorine, chloride salts, phosphoric acid, and sodium hydroxide. The corrosion resistance of the two is the same, with the exception that titanium is superior in resistance to solutions of chlorine, chlorides, and dilute hydrochloric acid. If the price of titanium is reduced to that of stainless steel, it will give stainless steel competition because of its lighter weight and higher strength.—INCO

22 **Materials Selection Chart.** CORROSION FORUM (EDITOR: M. HOOVER). *Chem. Eng.* 57, No. 8, 197-200 (1950).

Article indicates that carbon steel should give satisfactory service in dry gaseous chlorine at temperatures up to 70 F. Type 304 stainless steel will give better service. Moist chlorine gas requires Hastelloy C or Durichlor for satisfactory service at temperatures up to 70 F.

23 **Construction Materials in the Paper Industry,** Part II—Bleaching. CORROSION FORUM (EDITOR: M. HOOVER). *Chem. Eng.* 57, No. 10, 217-223 (1950).

High-silicon irons, cements, nickel, nickel alloys, and coatings are evaluated in their resistance to moist chlorine and to chlorine compounds.

24 **Silicate Cements.** R. B. SEYMOUR AND R. H. STEINER. CORROSION FORUM (EDITOR: M. HOOVER). *Chem. Eng.*, 59, No. 3, 268-286 (1952).

Graph indicated that the cements give satisfactory service in chlorine gas at temperatures up to 900-1000 F.

25 **Hastelloy Alloy C.** E. D. WEISERT. CORROSION FORUM (EDITOR: M. HOOVER). *Chem. Eng.*, 59, No. 6, 297-312 (1952).

Graph shows 0.002 to 0.02 inches per year corrosion at temperatures between 50 and 250 F for wet chlorine gas. Satisfactory for water saturated with chlorine at room temperature.

26 **Reinforced Polyester Plastics.** R. B. SEYMOUR AND R. H. STEINER CORROSION FORUM (EDITOR: M. HOOVER). *Chem. Eng.*, 59, No. 12, 278-286 (1952).

Graph shows satisfactory resistance to dry chlorine gas and to saturated chlorine water at temperatures up to about 100 F.

27 **High Impact Styrene Copolymers.** R. B. SEYMOUR AND R. H. STEINER. CORROSION FORUM (EDITOR: M. HOOVER). *Chem. Eng.*, 60, No. 1, 254-262 (1953).

Graphs shows satisfactory resistance to dry chlorine gas and to saturated chlorine water at temperatures up to about 160 F.

28 **Lead and Lead Alloys.** K. H. ROLL. CORROSION FORUM (EDITOR: M. HOOVER). *Chem. Eng.*, 60, No. 2, 264-280 (1953).

Graph shows lead as fairly resistant to dry chlorine at temperature up to about 220 F.

29 **Glassed Steel.** E. A. SANFORD AND O. J. BRITTON. CORROSION FORUM (EDITOR: M. HOOVER). *Chem. Eng.*, 60, No. 3, 294-304 (1953).

Graph indicates that glass lined steel is resistant to wet chlorine gas at temperatures up to about 215 F.

30 **Fused Quartz.** JOSEPH GIALANELLA. CORROSION FORUM (EDITOR: M. HOOVER). *Chem. Eng.*, 60, No. 4, 302-305 (1953).

Fused quartz is claimed to be inert to all halogens except fluorine. Quartz products can withstand temperatures up to 1500 C for short periods. They can be used continuously at temperatures up to 1000 C.

31 **Enter Hastelloy F.** CORROSION FORUM (EDITOR: M. HOOVER). *Chem. Eng.*, 60, No. 6, 318-320 (1953).

An attempt was made to produce an alloy intermediate in price, corrosion resistance and workability. Resistance to both oxidizing and reducing agents was desired. Out of about 250 alloys tested, only Hastelloy F remained. A few tests were conducted in wet chlorine at room temperature and in hypochlorite solutions. Hastelloy F would not resist wet chlorine satisfactorily. It was resistant to cold calcium hypochlorite solution containing 10 percent available chlorine.

32 **Electrolytic Chlorine Production.** *Chem. & Met. Eng.*, 53, No. 1, 227-228 (1946) Jan.

Comparison of standard American materials of construction and German construction materials for electrolytic chlorine manufacture. U. S. Materials: Hard rubber brine lines; stoneware lines, coolers, brine caps and sulfuric acid drying towers for wet chlorine; steel pipe traps, condensers and storage tanks for dry chlorine; cast iron pumps and compressors. German Chlorine equipment: Rubber lined, glass and brick lined or acid proof tile—porcelain cement lined cells. Covers for cells were sandstone slabs, rubber covered steel or concrete. Wet chlorine from cells carried in stoneware pipe and rubber lined mains. Surface coolers made of rubber lined steel box with stoneware coil containing water. Unlined steel box used if chlorine is inside coil. Stoneware or rubber and brick lined steel contact coolers used. Sulfuric acid drying towers rubber lined with inner course of brick work. Plastic and stoneware towers also used. High silicon cast iron used in circulation of sulfuric acid.

33 **Chlorine Handling in Pulp Mills.**[21] E. L. CROWLEY. *Paper Ind.*, 33, No. 11, 1311-1312 (1952) February.

Flexible metal hose of Monel, stainless or copper, copper figure S-bends or flexible elbows (Barco type) are different ways to hook a car to the mill lines. Two methods of packing chlorine valves to hold gas and be of free movement are a bellows-sealed valve which has Monel or stainless steel bellows and Teflon packing. Two valves in satisfactory service for 18 months are packed with two rings of Teflon and the balance of the stuffing box is filled with a Monel ferrule. While wrought iron works well with dry chlorine, either liquid or gaseous, it lasts only a few minutes in the presence of water and chlorine. Consequently Hastelloy C pipes and valves where chlorine and water are intermixed as when feeding chlorine into a pulp slurry are necessary. Once chlorine is in water solution, hard rubber lined equipment is necessary.

34 **Improved Enamels Extend Life of Steel Chlorination Tubes.** L. E. DUBE AND N. STORDAHL. *Steel*, 129, No. 17, 70-72, 99 (1951).

Slip compositions and firing techniques were modified to ease corrosion problem in black pipe used for fluxing and degassing aluminum alloys. Average life of ten minutes was multiplied 15 to 25 times, within cost limits. Liquid enamel, called "slip," is basically composed of clay, glass and oxides, plus other additions which determine special character. General practice is to apply an initial or ground coat and fire it. The method used to coat the inside is to close one end of the tube, fill it with slip and let it drain slowly. The enamel coating is a two-coat application designed primarily to resist corrosion. The importance of coating cost is discussed.

35 **Lining for Fused Salt Electrolytic Cells.** A. I. S. DUNCAN, J. G. MOORE AND I. C. I., LTD. *Chem. Abstracts*, 45, 3740h (1951), British Patent 647, 313, Dec. 13, 1950.

In cells for the electrolysis of fused salt or salt mixtures, a lining is provided for the protection of the refractory wall of the cell from attack by chlorine, sodium oxide, etc. A satisfactory lining or shield is made of mild steel. The lining prevents contact of the fused electrolyte with the refractory wall and thus eliminates contamination of the electrolyte.

36 **The Attack of Aluminum by Chlorine —I, High Pressure Investigation.** M. G. Evans. *Chem. Abstracts*, 30, 7981-4 (1936); *Mem. Proc. Manchester Lit. Phil. Soc.*, 79, 13-28 (1935).

Over a region of relatively high pressures (100-600 millimeters) the rate of surface attack of aluminum by chlorine is dependent on pressure. The rate of activation is 2000 calories. The aluminum surface condition affects the nature of the rate curves. The kinetics and the X-ray investigation furnish evidence on the mechanism of the reaction.

37 **Industrial Chemicals.** W. L. FAITH, D. B. KEYES AND R. L. CLARK. John Wiley & Sons, New York (1950), 216-223.

Described handling of chlorine gas after formation by salt electrolysis. Notes use of stoneware, glass and rubber-lined lines for wet chlorine. Iron centrifugal compressors with sulfuric acid sealing liquid discussed.

38 **Materials for the Construction and Protective Coating of Equipment for Production of Pulp by the Chloro-Alkaline Process.** D. M. FLYATE. *Chem. Abstracts*, 32, 8134-7 (1938). Tsentral. Nauch.—Issledovatel. Inst. Bumazh. Prom. Materialy 1937, No. 25, 99-115; cf. *Chem. Abstracts*, 29, 7250-3; 30, 7329-5.

The resistance to corrosion of various metals, ceramic materials and rubber, ebonite, Faolite and Bakelite to the repeated alternate action of chlorine gas and aqueous hydrochloric acid was substantially the same as previously reported. The high resistance of chlo-

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rinated rubber and divinylacetylene coating to chlorine and hydrochloric acid under actual pulping conditions is confirmed. Polymerized divinylacetylene showed good resistance to mechanical friction. Forty references.

39 **Corrosion. Recent Developments in Alloys as Construction Materials for Severe Corrosion Services.** M. G. FONTANA. *Ind. Eng. Chem.*, **39,** No. 10, 101A-102A (1947) October.

Description of composition, properties, applications and results of corrosion tests of Chlorimet 2 and 3 are summarized. These alloys are suitable for handling wet chlorine.

In general, Chlorimet 2 is preferred for reducing conditions and chromium bearing Chlorimet 3 for oxidizing conditions.

40 **New Alloys for Severe Corrosion Services.** M. G. FONTANA. *Chem. Eng.*, **53,** No. 10, 114-115 (1946) Oct.

High nickel-molybenum-chromium and nickel-molybdenum alloys suitable for handling all concentrations of wet chlorine. Describes hardening and effects of heat treatment on Chlorimet 3 (60 nickel-18 molybdenum-18 chromium) and Chlorimet 2 (63 nickel-32 molybdenum).

41 **Graphite Heat Exchangers, Parts I and II.** C. E. FORD. *Chem. Eng.*, **54,** No. 1, 92-96 (1947) Jan.; No. 2, 132-135 (1947) February.

Physical, thermal and corrosion-resistant properties of impervious graphite are reviewed, its reaction to specific chemical reagents tabulated and design and operation of graphite heat exchangers discussed. Impervious graphite possesses the unusual combination of chemical inertness and high thermal conductivity. Mechanically, it may be compared with grey cast iron. Material is much stronger in compressive strength than in tensile strength and there is practically no elongation under tension. It resists wet and dry chlorine.

Operating data from a 305,000 BTU/hour graphite precooler are given. A mixture of chlorine, carbon dioxide, water vapor and air is cooled from 85-55 F by cooling water in this impervious graphite shell and tube heat exchanger. Shells and baffles are steel, rest are graphite.

42 **Nickel & High Nickel Alloys.** W. Z. FRIEND. *Ind. Eng. Chem.*, **39,** 1228-34 (1947) October.

A literature survey concerning applications of nickel and its alloys. States that considerable use has been made of nickel and Monel equipment in organic chlorinations and other processes involving the use and handling of chlorine or hydrogen chloride under essentially anhydrous conditions. Says nickel and nickel alloys are among the materials most resistant to chlorine and hydrogen chloride at high temperature. Nickel, the most resistant, is useful for continuous service at 1000 F. Mentions use of sulfur free carbon lined nickel tubes for chlorination reactions at 1500 F. A water jacketed nickel tube is used in handling chlorine gas at an inlet temperature of 2000 F. Hastelloy C requires heat treatment after welding if it is to be used for handling wet chlorine gas. Hastelloy C is annealed at 2200-2250 F and cooled rapidly. J. V. Welding, **25,** p. 1179-82 (1946).

43 **Corrosion Resistance of Titanium, Zirconium, and Stainless Steel; Mineral Acids.**[12] LEX B. GOLDEN, I. ROY LANE, JR., AND WALTER L. ACHERMAN. *Ind. Eng. Chem.*, **44,** 1930-1935 (1952) Aug.

Corrosion rates for titanium, zirconium, and 20-29 chromium-nickel type stainless steel were determined in various concentrations of sulfuric, hydrochloric, nitric, phosphoric, and mixed acids. Results in sulfuric and hydrochloric acids showed that, in general, all three materials show greater resistance to corrosion in air-free solutions than in air-saturated solutions. In sulfuric acid solutions the stainless steel is superior to titanium under all conditions, whereas zirconium excels stainless steel in all sulfuric acid solutions below 80 percent concentration. The three metals show excellent resistance to all concentrations of nitric acid. In mixed acid solutions both titanium and stainless have better corrosion resistance than zirconium. At lower temperatures the addition of small amounts of nitric acid to sulfuric inhibits corrosion of both titanium and stainless steel but increases that of zirconium. Of the three metals only zirconium is fully resistant to corrosion in hydrochloric acid solutions. Titanium is satisfactorily resistant to all concentrations of phosphoric acid only at lower temperatures. The stainless steel shows better resistance than zirconium, especially in boiling solutions. Titanium is fully resistant to an atmosphere of water-saturated chlorine, while zirconium, type 316 stainless steel, and 20-29 chromium-nickel stainless steel are badly attacked.

44 **Halides as Acid Pickling Inhibitors.**[13] K. F. HAGERS AND M. ROSENTHAL. *Corrosion*, **6,** No. 10, 344-346 (1950) Oct.

A new group of inorganic inhibitors consists of halogens and halides. Investigations were conducted in order to observe the mechanism of retardation and acceleration of acid pickling by the addition of compounds to determine the effect of halogens and halides on the acid attack against ferrous metals. Inhibition of acid attack on base metal was found to increase with the increase of atomic weight of the halogen in the molecules. The rate of oxide removal on rusted ferrous metal surfaces was not noticeably affected regardless of the halide used. Iodine and iodides were found to be effective inhibitors in concentrations of 0.1 percent and over. Bromine and bromides were next in effectiveness, and chlorine and chlorides were also inhibitors, but iron and fluorides were accelerators of acid attack on base metal. The theory of halide inhibition of iron dissolution may be in the formation of a passivating monomolecular film of the iron halide. Mild steel (SAE 1010) pieces were used as material for test specimens. Tests were made in pickling solutions of 1 and 5 normal sulfuric acid and 5 percent nitric acid, using varying concentrations of inhibitors and several different temperatures for a number of test durations. Tables of results and 3 references are given.—INCO.

45 **Ceramic Coatings for Metallic Parts and Other High-Temperature Applications.** W. M. HARRISON, D. G. MOORE, AND J. C. RICHMOND. *Chem. Abstracts*, **41,** 4903h (1947). Nat'l. Advisory Comm. Aeronautics, Tech. Note No. 1186, 17 pp. (1947).

Coatings consisting of various frits were exposed to air and corrosive atmospheres such as oxygen, carbon monoxide, carbon dioxide, water, chlorine, sulfur and hydrogen sulfide.

46 **Selection of Protective Coatings for Chemical Fumes Resistance.** C. C. HARVEY. *Corrosion*, **6,** No. 10, 323-326 (1950) October.

Test panels were exposed at room temperature in fumes over 15 percent hydrochloric acid or to about 0.05 percent chlorine fumes saturated with water. In tests involving 295 selected proprietary coating formulations, vinyl and asphalt mastic coating vehicles exhibited superior resistance to hydrogen chloride fume conditions. Carbon black, titanium dioxide, chromic oxide and the organic pigments toludine red, phthalocyanine green, phthalocyanine blue and hansa yellow were the most satisfactory finish coat pigments tested. The use of a primer on the rusted field test panels appeared to be essential to good performance in any coating system tested. Red lead was superior to zinc dust or zinc chromate as the inhibitive primer pigment. Medium oil alkyd primer containing free linseed oil to improve wetting characteristics exhibited superior performance in a system, although they were less resistant when not protected by finish coats. Surprisingly, wire-brushed rusty panels performed as well as, and in most cases better than, clean, pickled or sand-blasted panels when systems incorporating primers with good surface wetting properties were used.

47 **Corrosion of Steel by Gaseous Chlorine.**[14] G. HEINEMANN, F. GARRISON AND P. HABER. *Ind. Eng. Chem.*, 38, 497-9 (1946) May.

Information is presented on the rate of corrosion and the ignition temperature of sheet steel in commercially dry chlorine gas at temperatures from 77 to 251 C for exposure periods between 12 and 480 minutes. Gradual increases in the corrosion rate are noted as the temperature is raised to 248 C. At 251 C the sheet steel coupons show a greatly accelerated corrosion rate of approximately 31 inches penetration per year (170,000 mg per sq dm per day) for exposure periodes of less than 30 minutes. After 30 minute-exposure at 251 C the sheet steel coupons ignite to give corrosion rates in excess of 170,000 mg per sq dm per day.

48 **Chlorine-Caustic Soda.** J. V. HIGHTOWER. *Chem. Eng.*, **55,** 112-116 (1948) December.

Described equipment utilized in electrolytic chlorine plant near Houston. All chlorine piping in cell room is pyrex glass. Joints wrapped with lead strips. Chlorine leaves cell room saturated with water vapor at 180 F. Most moisture removed by passing chlorine through primary and secondary banks of 3-inch diameter Pyrex gas tubes, which are sprayed with cooling water. Primary tubes cool chlorine to 105 F.

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Secondary tubes, sprayed with refrigerated water, reduce temperature to 60 F.

Cooled chlorine further dried in 4 foot diameter by 30 foot high ceramic towers. Bell and spigot joints of rings comprising the towers are caulked with asbestos rope covered with putty-like material. Uprising chlorine placed in intimate contact with downcoming sulfuric acid through use of movel, ceramic baffle system. From ceramic towers, chlorine is passed through coke packed steel towers for removal of sulfuric acid and organic material. Chlorine liquefied by passage through steel shell and tube heat exchangers where gas is chilled by liquid Freon vaporizing outside tubes. The liquid chlorine is shipped to its destination through 10,300 foot long, 3-inch diameter, seamless steel pipe line.

49 **Handling Chlorine.** J. V. HIGHTOWER. *Chem. Eng.*, **56,** No. 1, 96-98 (1949) January.

Describes unique chlorine handling system in a plant manufacturing ethylene oxide and other chemicals. Chlorine is forced out of tank car through steel eductor pipes by compressed air which was dried to a dew point of —50 F. This is only point of compressed air-chlorine contact in the system.

Tank car determined to be empty when compressed air replaces chlorine in exit flowmeter, causing float to drop and actuating switch. Liquid chlorine heated to 80 F in steel pipe coils which are immersed in steel, hot water box. Heated liquid chlorine stored in uninsulated steel tanks. Before use in chemical process, the liquid chlorine is passed through steel shell and tube vaporizer. Hot water is in tubes. Double tube sheet provided to minimize chlorine leakage around tubes. The pressure of the chlorine is raised to 44 psi by vaporizer.

50 **Instrumentation in a Modern Chlorine Handling Plant.** J. M. HILDYARD. Paper before Electrochem. Soc., Cleveland, April 19-22, 1950; *J. Electrochem. Soc.*, **97,** No. 11, 367-376 (1940) Nov.

The control equipment for a modern chlorine handling plant is described and analyzed. The process consists of equipment for collecting, cooling, drying, compressing and liquefying chlorine gas. Personal supervision of the equipment by the operators was reduced by the control means employed.

Some information is given for the selection and installation of instruments for chlorine plants. If the chlorine is absolutely dry and the lines are dry, valves with cast iron bodies and stainless trim, except for stems, are acceptable. Stainless steel stems are not permissible in sliding stem valves but are acceptable on rotary stem valves. The stems of sliding stem valves should be of Hastelloy C. Some of the crevices in the valves do not dry out, and when the line is used again, valve trouble nearly always develops. The most satisfactory solution is to use Hastelloy C trim throughout. Valves in lines that are subjected to frequent steaming should have stainless steel bodies to resist the corrosive action of ferric chlorine which forms when the line is returned to use.

51 **Chemical Handling Materials.**[15] L. R. HONNAKER AND M. L. MONACK. *J. A.W.W.A.*, **45,** No. 5, 469-475 (1953).

Table 1 lists the following materials as suitable for handling chlorine water: rubber, Uscolite, polyvinyl chloride, vinylidene chloride, furan resins.

52 **Plastics in Anticorrosive Applications.** J. L. HUSCHER. *Chem. & Eng. News*, **31,** No. 9, 860-863 (1953).

Phenol formaldehyde (asbestos filled) is listed as completely resistant to chlorine gas, dry and wet, at 70, 140, and 200 F. Furfuryl alcohol (asbestos filled) and polyester (glass filled) are listed as completely resistant to dry gas at 70, 140 and 200 F and to wet gas at 70 F. The table indicated slight attack, but recommended for service with wet gas at 140 F. Some attack, use doubtful, is listed for wet gas at 200 F. Polyethylene is listed as being slightly attacked, but recommended for service with dry gas at 70 and 140 F and with wet gas at 70 F. Not recommended for wet gas at 140 F. Complete decomposition is listed for 200 F with both dry and wet gas. Polyvinyl chloride (unplasticized) is listed as completely resistant to dry gas at 70 and 140 F and to wet gas at 70 F. Some attack, use doubtful is listed for wet gas at 140 F. It is not recommended for dry or wet gas at 200 F. Polymethylmethacrylate is listed as completely resistant to dry gas at 70 F. Slight attack, but recommended for service is the listing for dry gas at 140 F and for wet gas at 70 and 140 F. It is not recommended for dry or wet gas at 200 F. Rubber resin blends are listed as completely resistant to dry and wet gas at 70 F. Some attack, use doubtful is the listing for dry and wet gas at 140 F. They are not recommended for use with dry or wet gas at 200 F.

53 **Corrosion Resistance of Commercially Pure Titanium.** G. E. HUTCHINSON AND P. H. PERMAR. *Corrosion*, **5,** No. 10, 319-324 (1949); Oct. Discussion, 324-325.

Wet chlorine gas is not corrosive to titanium. Titanium has shown complete immunity from corrosion by chlorine saturated water and water saturated chlorine gas in laboratory and plant exposure tests. The only discernible effect of exposure to water saturated chlorine gas is an occasional transparent brown stain on the metal surface. Finely divided titanium may be ignited and rapidly consumed when exposed to pure, dry chlorine gas. The addition of water vapor apparently inhibits the reaction. Shavings of titanium may ignite in chlorine containing less than approximately 0.005 percent by weight of water, but apparently depends on (1) the state of subdivision of the surface; i.e., whether or not small particles (such as are formed on a rough machined surface) are present, and (2) the temperature. No data available on temperature at which spontaneous combustion begins.

54 **Use of Stainless Steels in Contact with Chlorine.** H. O. KAUFFMANN AND R. L. MCEWEN. *Chem. Abstracts*, **34,** P705-5 (1940); U. S. Patent 2,174,516, Oct. 3, 1939.

A stainless steel is rendered resistant to active chlorine by preliminary treatment with a persulfate such as that of potassium (suitably in dilute aqueous solution at room temperature or a higher temperature for 6 to 48 hours).

55 **Chlorine and Caustic in Italy.**[16] R. L. KENYON AND P. GALLONE. *Ind. Eng. Chem.*, **45,** No. 6, 1162-1172 (1953) June.

A discussion on the manufacture of chlorine by electrolysis of sodium chloride in the mercury amalgam cell, with special reference to the de Nora cell. The electrolyte for the amalgam cell which is a substantially saturated solution of sodium chloride should be pure in the ideal case. Chromium, nickel, vanadium and heavy metals in general are very harmful to amalgam stability. Materials of construction include steel, carbon and stainless steel, and cast and cast silicon iron. Illustrations, flow sheets, 17 references.—INCO.

56 **Encyclopedia of Chemical Technology.** R. E. KIRK AND D. L. OTHMER. The Interscience Encyclopedia, Inc., New York (1947) p. 379-381.

Discusses in detail the handling of chlorine gas immediately after production by brine electrolysis. Describes steps as follows:

1. Gas collection in stoneware, manifolds. (Gas contaminants—water, brine spray, carbon dioxide, air, hydrogen).
2. Stoneware of glass pipe coolers.
3. Sulfuric acid drying towers (exit moisture concentration = 0.5 mg/liter).
4. Cast iron compressors (sulfuric acid lubricated).
5. Sulfuric acid separators.
6. Condensers.
7. Non-condensable gas purge trap. Sniff gas system.
8. Storage.

57 **Diaphragm Control Valves—Corrosion Forum.** A. J. KOCH. *Chem. Eng.*, **54,** No. 6, 207-208 (1947) June.

Discusses design and materials of diaphragm control valves, used for gas, wet and dry, acids and other chemicals. Chlorine and hydrogen chloride can be handled with iron or steel valves with 18-8 stainless trim, but only if dry. If the chlorine is apt to be wet, cast iron bodies with Hastelloy B trim have been used.

58 **Large Scale Laboratory Production of Ductile Zirconium.** W. J. KROLL, C. T. ANDERSON, H. P. HOLMES, L. A. YERKES AND H. L. GILBERT. *Trans. Electrochem. Soc.*, **94,** No. 1, 1-20 (1948).

The chlorinator consisted of a vertical shaft furnace and a condenser. Shells of the furnace and the condenser were made of welded nickel sheet. Furnace was lined with silica brick set in mortar of silica flour and sodium silicate. A conical water-cooled bottom with an iron elbow was used for introducing the chlorine and for removing the chlorinated residue. Chlorine piping and controls were made of iron.

59 **Recent Progress in the Metallurgy of Malleable Zirconium.** W. J. KROLL, A. W. SCHLECTEN, W. R. CARMODY, L. A. YERKES, H. P. HOLMES AND H. L. GILBERT. *Trans. Electrochem. Soc.*, **92,** 99-113 (1947).

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Chlorinator consisted of a vertical silica tube equipped with a nickel elbow at upper end to connect to the condenser. The lower end of the silica tube was held by a water-cooled Invar ring soldered to an iron base.

60 **Ductile Zirconium from Zircon Sand.** W. J. KROLL, A. W. SCHLECTEN AND L. A. YERKES. *Trans. Electrochem. Soc.*, **89,** 263-276 (1946).

Chlorinator was made of a vertical silica tube. Condenser was made of sheet nickel. Connection consisted of a graphite elbow. Chlorine was introduced into an iron elbow through iron pipe at bottom of chlorinator.

61 **Materials of Construction for Chemical Process Industries.** J. A. LEE. McGraw-Hill Book Co., New York (1950) p. 93, 331, 332, 336, 367.

Lists materials of construction recommended for manufacture of chlorine by electrolytic process and hydrochloric acid hydrolysis (p. 93-97). States effect of handling chlorine on steel, high silicon irons, porcelain, vitreous silica, Worthite, silicones, rubber lining, carbon and graphite, Hastelloy C, wood, Durimets, nickel alloys, stoneware, Haveg, glass-lined steel, stainless steel, Saran and organic protective coatings. Temperature, moisture and pressure are considered (p. 97-103). Mentions use of lead to handle chlorine in hypochlorite production (p. 336). Recommends materials for pulp chlorination equipment. Tile-lined concrete, rubber covered steel, wood. Other materials discussed are: stainless steel, Hastelloy C, glass, iron, high silicon iron, Durimet and Monel (p. 365-367).

62 **Corrosion of Silver in A Water-Saturated Chlorine Atmosphere.**[17] H. B. LINFORD AND M. J. FORD. *Chem. Abstracts,* **42,** 1865d (1948); *Trans. Electrochem. Soc.*, **93,** No. 1, 16-26 (1948).

The corrosion rate of pure silver (better than 99.7 percent) in a saturated chlorine atmosphere initially indicated that above 44 C a negative temperature coefficient was obtained. After an extended period of time the temperature coefficient was positive up to about 90 C. The effects are explained on the basis of concentration of active agent and diffusion through the film of silver chloride of the active agent.

63 **Corrosion Resistance of Anodized and Unanodized Titanium.** CHUK-CHING MA AND E. M. PARES, JR. *Ind. & Eng. Chem.*, **43,** No. 3, 675-679 (1951).

Titanium is resistant to boiling water saturated with chlorine and chlorine saturated with water at 80 C.

64 **Equipment and Construction Materials for Seventeen Important Chemicals.**[18] Thirteenth Annual Report on Materials of Construction. *Chem. Eng.*, **55,** No. 11, 99-115 (1948) Nov.

Describes materials utilized in chlorine treatment operations from the electrolysis cell to shipment in cylinders. Mentions use of chemical stoneware, pipe and rubber lined mains. Stone lined, glass lined and rubber lined coolers are noted. Brick lined heat exchanger. Stoneware for sulfuric acid drying towers. Steel pipe lines, traps, condensers and storage tanks handle the dried gas. Cast iron pumps and compressors. High silicon iron pumps used when sulfuric acid present. Chlorine shipped in steel cylinders.

65 **Fourteenth Annual Report on Materials of Construction.** S. D. KIRKPATRICK AND J. R. CALLAHAM. *Chem. Eng.*, **57,** No. 11, 107-154 (1950) Nov.

Indicates resistance of carbon, Chlorimet-3, plastic coatings, rubber coatings, Durimet-20, Duriron, glass, steel, lead, nickel, rubber, silicones, stoneware, tantalum and Worthite to chlorine. The effects of moisture and temperature on activity of chlorine with these materials is described.

66 **Organic Materials vs. Corrosion.** Fifteenth Annual Report on Materials of Construction. *Chem. Eng.*, **59,** No. 11, 147-176 (1952).

Table shows the following classifications for use with chlorine:

Class I service—natural rubber, vinylidene chloride.

Class II service—butadiene-styrene rubber, neoprene, vinyls.

Class III service—polyethylene.

Class IV service—phenolics, furanes, epoxys, oleoresins chlorinated rubber, styrene-butadiene, bitumen.

67 **Anhydrous Chlorides Manufacture.** (Germany). F. H. MCBERTY. #PB-22626 (F.I.A.T. Final Report No. 774-1946).

Aluminum Chloride: Various reactors consisted of steel shells lined with layers of firebrick and asbestos paper. Lining of chlorine lines was not specified. Condensers were made of mild steel. Gas scrubbers were rubber lined steel. Temperatures up to 1000-1100 C. in the reactors.

Ferric Chloride: Reactor furnace was lined with Didier (Wiesbaden) firebrick of high-alumina content, comparatively free of heavy metals. The bottom of the furnace (principal reaction zone) was made of steel, water-jacketed. Temperatures and chlorine piping were not specified. Polyvinyl hoses were used to transfer ferric chloride.

Silicon Tetrachloride: Shaft type chlorination furnace was a steel shell lined with 250 millimeters of firebrick. Gas outlet was lined also. Chlorine was introduced through an unlined steel section.

Zirconium Tetrachloride: Chlorination furnaces consisted of steel shells, lined with 260 millimeters of "Resistal" firebrick and 130 millimeters of "light fire Clay" insulating brick. Condensers consisted of unlined steel, cone-bottomed towers. These were air cooled. Exhaust gases passed through rubber lined steel scrubbers.

68 **Aluminum (Bus Bars) for Electrolytic Alkali-Chlorine Plants.** G. MEYER. *Chem. Abstracts,* **34,** 3182-1 (1940); *Aluminum,* **21,** 333-334 (1939).

The usual copper bus bars were replaced by aluminum bus bars of 1.2 square decimeter section whereby 17 tons of electrolytic copper was recovered. The joints of the aluminum bars were welded. Where aluminum to copper connections were necessary these were made by inserting copper clad aluminum sheets between the copper and aluminum so as to avoid formation of local galvanic couples which would start corrosion. Furthermore, a coat of lacquer was applied to the joints to prevent humidity and chlorine gases from penetrating the contact faces. No trouble has been experienced since installing the aluminum bars in December 1937.

69 **Carbon and Graphite.** J. P. OLIVER. The Corrosion Forum, *Chem. Eng.*, **59,** No. 9, pp. 276-287 (1952).

Carbon—inert to halogens at all concentrations at boiling temperatures, except strongly oxidizing aqueous solutions. Threshold oxidation temperature in air is given as 660 F.

Graphite—bromine, 100 percent, rapid disintegration; chlorine, 100 percent, inert; iodine, 100 percent, inert; fluorine, 100 percent, attacked. Threshold oxidation temperature in air is listed at 750 F.

70 **Aluminum in the Chemical Industry.** W. J. PASSINGHAM. *The Mining J.*, **226,** No. 5762, p. 65-67 (1946) January 26.

Advantages of the use of aluminum in the chemical industry are discussed briefly. Choice of aluminum or aluminum alloy, problems of joining, reaction of aluminum to water, steam, fluorine, chlorine, bromine, hydrogen peroxide, sulfur, sulfuric acid, and a few uses are discussed.

71 **Tantalum.** A. L. PERCY. The Corrosion Forum, *Chem. Eng.*, **59,** No. 4, pp. 259-264 (1952).

Tantalum is resistant to chlorine gas (wet or dry) at temperatures up to 300 F. The metal has not been evaluated at higher temperatures.

72 **Silver and the Platinum Metals.**[19] J. M. PIRIE, *Metal Industry* (London), **83,** No. 10, 188-190 (1953) Sept. 4.

Discussion of silver and the platinum metals in chemical engineering. Silver, resistant to chemical attack under a wide range of conditions, is the best metal for use in contact with halogens and halogen acids. Silver lining is an important application to chemical process equipment. Platinum and its alloys are used in the construction of electrodes for electrolytic oxidation, and for handling molten glass. Use of silver and platinum alloys as industrial catalysts is pointed out. Photographs.—INCO.

73 **Selecting the Most Chlorine-resistant Paints.** A. P. POLOZOV AND R. P. GOVOROVA, *Chem. Abstracts,* **32,** 9525-3 (1938).

$PbSb_2O_6$ showed a high resistance against wet and dry chlorine. Addition of 20 percent barium sulfate will cause no harm. A further increase of barium sulfate lowers the resistance. The use of lead sulfate, barium chromate and

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nickel phosphate with 40 percent barium sulfate is recommended. Good acid-resistant films were also obtained from complex varnishes containing lignite bitumen and phenol-aldehyde resins.

74 **Anode Cover for Electrolytic Salt Solutions.** C. N. RICHARDSON. *Chem. Abstracts*, 41, 7284e (1947); U. S. Patent 2,428,584, Oct. 7, 1947.

To prevent corrosion of metallic connections by liberated chlorine, the cell containing the salt solution is covered by a solid slab of graphite laterally extending over the side walls of the cell.

75 **Silver Alloys with Increased Resistance to Chlorine.** (In German). J. SCHATZ. *Werkstoffe u. Korrosion*, **1**, 248-249 (1950) June-July.

Briefly tells how multivalent metals which form a solid solution with silver (especially cadmium, zinc and lead) greatly inhibit the progressive formation of silver chloride at higher temperatures. Includes graphed data and photomicrographs.

76 **Corrosion of Pressure Vessels Used for Storage or Transport of Gases.** P. SCHLAPFER AND A. BUKOWIECKI. Schwerz. Ver. Gas u. Wasserfach., Monats-Bulletin (Switzerland), V. **28**, 105-113 (1948); *Chem. Abstracts*, **42**, No. 21, 8145 (1948) Nov. 10; *Iron & Steel*, **22**, 95 (1949) March.

Steel containers for liquefied gases are generally made of 0.3 to 0.45 percent carbon steel; higher carbon content is undesirable. Lighter construction is allowable with nickel or nickel-chromium-molybdenum alloy steels; their corrosion resistance is, however, often no better than that of steel. Various aluminum alloys are in use and proper for most noncorrosive gases. Very few of the compressed gases even including chlorine, nitrous oxide, sulfur trioxide, hydrogen chloride or hydrogen sulfide attack steel or aluminum if properly dried. It is most important to avoid the presence in the bottles of small amounts of water. Examples are given of severe corrosion in pressure vessels with oxygen or illuminating gas in the presence of small amounts of water. The attack of metal is particularly frequent if a separate aqueous phase is present locally on the walls; this holds for permanent gases like boron fluoride, illuminating gas, oxygen and compressed air as well as for liquefied gases like chlorine, hydrogen chloride, phosgene, sulfur dioxide, hydrogen sulfide and carbon dioxide; also for chlorinated hydrocarbons. With illuminating gas the hazard of transcrystalline cracks can be avoided by using steel with less than 0.4 percent carbon. In aluminum vessels the same gases are dangerous. The test work has not been completed.

77 **Plastic Equipment Reference Sheet, No. 22.** R. B. SEYMOUR AND R. H. STEINER. *Chem. Eng. Progress*, **49**, No. 6, p. 330 (1953).

Plasticized vinyl resins showed the following chemical resistance ratings: No attack by wet chlorine gas at 75 and 150 F; no attack by dry chlorine gas at 75 F; some attack by dry chlorine gas at 150 F; no attack by hydrochloric acid at 75 and 150 F.

78 **Stability of Metals in Plants Producing Chlorine Gas and Sodium Nitrate.** A. I. SHULTIN AND I. A. KOSYAKOVA. *Chem. Abstracts*, **36**, 997-9 (1942); *Dorroziya i Borba s Nei*, **5**, No. 1-2, pp. 126-137 (1939).

Experimental work is reported. Under conditions of the reaction between nitric acid (d.1.42) and sodium chloride in the molecular ratio 3:1, at 100 C in both the gas and the liquid phase Silex (cast iron containing 15.75 percent silicon) and Mosilex (cast iron containing 15.3 percent silicon and 3.8 percent molybdenum) are entirely resistant. Chromex (2.39 percent silicon and 31.95 percent chromium) has good resistance. The nitric acid forms a protective film that is not destroyed by chlorine or nitrosyl chloride. The moisture content was high in the gas phase above the reaction medium. Dry nitrosyl chloride at 100 C is more corrosive than dry chlorine; nitrosyl chloride at this temperature forms compounds of the type MCl_2 NOCl and MCl_3NOCl with most metals (except nickel, magnesium and possibly chromium). The most resistant is nickel steel. Mosilex is next. Silex and Chromex, resistant to moist gases, are highly corroded by dry gases. At room temperature, nitrosyl chloride causes little loss of weight in Silex and Mosilex in 100 hours.

Pure dry chlorine is much less corrosive than pure moist chlorine at 100 C At 0 C liquid nitrosyl chloride is highly corrosive. Chromex alloy is comparatively resistant and pure nickel entirely resistant. Concentrated nitric acid and hydrochloric acid (3:1) at 60 C are much more corrosive than nitric acid and sodium chloride at 100 C. Still, even under these conditions, Chromex and Mosilex are sufficiently stable. Silex is unreliable. The products of corrosion absorb moisture forming a brown-reddish liquid. They dissolve in water with evolution of oxides of nitrogen, free chlorine and nitrogen. The solid (a yellow-red crust) is composed of ferric oxide, ferric chloride and silicon dioxide. Nickel and chromium steel and Hastelloy A cannot be used for equipment construction in plants producing chlorine.

79 **Corrosion Resistance of Steel and Cast Iron.** A. W. SPITZ. *Chem. Eng.*, **54**, No. 2, p. 135 (1947).

These metals are recommended for dry chlorine gas only. They are unsatisfactory for hydrochloric acid service.

80 **Chlorination of Zirconium Oxide.** W. W. STEPHENS AND H. L. GILBERT. *J. of Metals*, **4**, No. 7, pp. 733-737 (1952).

Experimental chlorinator was made of a mild steel shell with silica brick lining to form a vertical shaft. Nickel was used for the chlorine inlet, the charging port and the chloride discharge pipe. A chlorine gas preheater was made up coiling a thin wall ¼-inch nickel tubing into a helix and applying low voltage power to opposite ends of the tubing. In larger scale equipment the preheater was replaced with an electrically heated hot water chlorine evaporator made of iron. All chlorine piping was iron except the short inlet section.

81 **How to Move Liquid Chlorine by Pipeline.**[20] W. H. TELL. *Chem. Ind.*, **65**, No. 1, p. 52 (1949) July.

A two-mile elevated pipeline for transporting liquid chlorine to Shell Chemical Corporation synthetic glycerine plant at Houston from the nearby Diamond Alkali Co. plant is described. The pipeline is made of all-welded three inch seamless steel pipe and supported by hangers which, together with expansion loops permit expansion or contraction without stressing. Protection against excess hydrostatic pressure is afforded by a dual rupture disc system connected via a relief manifold to the vapor space of the receiving storage tanks. Internal corrosion of the pipe from dry chlorine is insignificant.

Safety relief valves on the storage tanks are protected against corrosion by silver rupture disc. Capacity of the line at a pressure drop of 45 psi is 6 tons/hour in summer and 10 tons/hour in winter. Chlorine is transferred to the line from weigh tanks by a blow-case system.

82 **Corrosion Handbook.** H. H. UHLIG, Editor. J. Wiley & Sons, (1948) p. 142.

Corrosion rates of steel in "commercially dry" chlorine at various temperatures are presented. (Source: Heinemann, Garrison & Haber, *Ind. Eng. Chem.*, **38**, 497-9 (May, 1946).

83 **Corrosion Handbook.** H. H. UHLIG, Editor. J. Wiley & Sons, (1948) p. 682.

Table 6 presents maximum service temperatures for different metals in "dry" chlorine.

84 **Uses of Tantalum and Columbium.** T. A. WOOD. Commonwealth of Australia, Dept. of Munitions, Munitions Supply Lab. Inform. Circ. No. 11, 18 pp. (1947).

Tantalite ores, frequently containing columbium, long have been mined in Australia, and have been shipped overseas for treatment. Commercial production in Australia is under consideration —hence this review of the properties and uses of the two metals. Tantalum is a platinum-white metal, with mechanical properties similar to those of mild steel, but it can be gas-hardened to about 600 VPN. It can be worked and formed readily. It is chemically inert to many substances, including chlorine and hydrogen chloride up to 150 C., and so finds many applications in chemical plants. It also is widely used in high-power radio tubes and for electrodes in rectifiers.

The carbide finds application in certain grades of cemented carbides. Columbium is a light grey metal, approximately the hardness of wrought iron. It is readily worked, formed, cut and spot welded. It resists nearly all chemical attack, and readily occludes gases—hence its uses as a getter in vacuum tubes. Its major use is as a carbide stabilizer in austenitic stainless steels. A comprehensive classified list of uses

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is given for both metals, together with a bibliography for the period 1929-1946.

85 **Effect of Chlorine on Refractory Materials.** SHUNKICHI YAMANOUCHI, NOBUO KAWAI AND TSUGITAKE KAWARADA. *Chem. Abstracts,* **44,** 7504i (1950); *J. Japan Ceram. Assoc.,* **54,** pp. 32-34 (1946); *J. Am. Ceram. Soc.,* **32,** No. 3, Ceram. Abstracts Sect. 83 (1949).

Cylindrical test pieces of chamotte were pressed at 150 and 200 kilograms per square centimeter and fired at cone 12 for one hour. Chlorine was passed over the test pieces during heating at 600, 700, 800, 900 and 1000 C at the rate of 0.5 liter per hour for 10 hours. The weight of the test pieces decreased and they became white owing to the evaporation of iron as ferrous chloride. The decrease in weight and crushing strength is remarkable for the test pieces heated at 1000 C. The elastic modulus was also measured on test pieces 1 x 2 x 15 centimeters which were pressed at 150-160 kilograms per square centimeter and fired at cones 12 and 15 for one hour. They were treated with chlorine at 900 C as above. Test pieces pressed at higher pressures are more resistant to chlorine attack.

86 **A Staff-Industry Collaborative Report—Modern Production of Chlorine and Caustic Soda.**[21] W. H. SHEARON, JR., F. CHRENCIK AND C. L. DICKINSON. *Ind. & Eng. Chem.,* **40,** No. 11, 2002-2010 (1948) Nov.

Discussion of raw materials, materials of construction, chlorine production, caustic preparation, hydrogen-chloride filling and storage systems, and instrumentation and safety. Among materials chosen as best compromise on basis of corrosion resistance and cost is nickel-clad equipment for handling hot caustic. For storage purposes, nickel-lined tanks are used for 73 percent caustic.

References

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2. NACE Abstract No. 301.
3. NACE Abstract No. 4843.
4. NACE Abstract No. 5288.
5. NACE Abstract No. 3602.
6. NACE Abstract No. 5375.
7. Bibliographic Survey of Corrosion, 1946-47, 4.3-24, Page 86.
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10. NACE Abstract No. 1589.
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12. NACE Abstract No. 5559.
13. NACE Abstract No. 872-A.
14. Bibliographic Survey of Corrosion, 1946-47, 2.3-50, Page 34.
15. NACE Abstract No. 7380.
16. NACE Abstract No. 6727.
17. Bibliographic Survey of Corrosion, 1948-49, 4.3.5-5, Page 123.
18. Bibliographic Survey of Corrosion, 1948-49, 1.5-1, Page 5.
19. NACE Abstract No. 7143.
20. NACE Abstract No. 3669.
21. Bibliographic Survey of Corrosion, 1948-49, 8.8.1-32, Page 312.

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Field Practices for Controlling Water-Dependent Sweet Oil Well Corrosion*

A Report of Technical Unit Committee T-1C on Sweet Oil Well Corrosion[1]
(Compiled by Task Group T-1C-1 on Field Practices[2]*)*

Abstract

Field practices used by 19 companies for controlling corrosion in water-dependent sweet oil wells are reported. Limits at which corrosion becomes detrimental are given in terms of percent water produced, iron concentration, coupon corrosion rate, percent wall reduction and frequency of equipment failure. Reports are given of the use of the following devices on flowing wells: injection valves, sidedoor chokes, tapered tubing, and special equipment. Consideration is given also to the minimizing of corrosion in gas lift wells and in pumping wells.

Accounts of the use of plastic coated and special alloy tubing are given. Other topics discussed include the use of liquid inhibitors, weighted inhibitors, stick inhibitors, pellet form inhibitors, inhibitor choke, and special techniques.

Introduction

TASK GROUP T-1C-1 was organized at a meeting of Unit Committee T-1C held in Chicago, Illinois in March 1955. The specific assignment given the task group was to determine current field practices for controlling corrosion in water-dependent sweet oil wells.

Last August the task group sent a questionnaire to a number of companies in the oil producing industry. The questionnaire was designed to ascertain current field practices used for controlling corrosion in water-dependent sweet oil wells.

Replies were received from 19 companies. Information found in the following paragraphs is in effect a summary of these replies.

The committee believes this report presents a consensus of the industry's field practices because it represents what is being done to control water-dependent sweet oil well corrosion in a large number of fields and wells. Areas in which these fields are located are given in Table 1.

Well Classification

All operators contacted considered equipment failure to be the most indisputable method for determining necessity for corrosion protection measures. This may be qualified by saying that a corrosiveness investigation is usually undertaken when equipment failure occurs.

Although one method may be considered more reliable than others, all operators reported use of a combination of methods. Twelve reporting companies used percent water produced, twelve used iron content, eight used coupons and thirteen used caliper surveys. Some operators reported use of surface conditions as a method for determining when protection was needed.

Thirteen operators established limits for part or all the corrosion detection factors. The following is a summary of the limits above which corrosion is considered detrimental:

Percent Water Produced

The limit on percent water produced may depend upon the field being considered. For low pressure, pumping and gas lift wells a limit of 40 to 60 percent water production is generally used. In East Texas fields the limit ranges from 70 to 80 percent water production. Two operators have set the limit for high pressure oil wells at 10 percent water production.

Iron Concentration (ppm)

Most operators did not set a definite limit on iron concentration because they considered it to have only comparative value. Two operators, however, set limits of 30 and 50 ppm. Two other operators expressed the limit in terms of 0.5 pound per day and 2 pounds per day iron in produced water.

TABLE 1—Location of Oil Fields and Wells

Area	Oil Fields	Oil Wells	CORROSIVE Fields	CORROSIVE Wells
1. Texas Gulf Coast	440	11,749	170	2350
2. Louisiana Gulf Coast and Mississippi	165	4,110	50	530
3. North Louisiana, Arkansas, and East Texas	71	11,818	33	1870
4. Others (Illinois, North Texas, California)	?	1,510	?	85
Total	676+	29,187	253+	4835

★Presented at a meeting of T-1 in Houston, Texas, October 18, 1955.
(1) H. E. Greenwell, Atlantic Refining Co., Dallas, Texas, chairman.
(2) J. T. Payton, The Texas Company, Houston, Texas, chairman.

Coupon Corrosion Rate (mpy)

One operator used a coupon corrosion rate limit of 0.5 mpy on two-week exposure. Two operators used 1 mpy, one 2 mpy and one 5 mpy.

One operator classified wells according to the severity of corrosion by the coupon method as follows: 0-1 mpy —little corrosion; 1-10 mpy—moderate corrosion; 10 plus mpy—severe corrosion. Another operator who does not currently use the method set a limit of 5 mpy.

Caliper Survey (Percent Wall Reduction)

Operators reported limits ranging from 20 to 30 percent wall reduction. This limit may depend also on the increase in wall reduction between surveys; hence, the limit was expressed by some operators as tubing life less than 3 to 5 years, 25 percent reduction in two years, and 10 to 20 percent reduction per year.

Equipment Failure (Frequency per Year)

Most operators have not set limits on this method because it involves an economic analysis and may vary by fields. Limits that have been set are as follows: $200.00 per year; pump repair expenses of $6.00 to $10.00; 4 jobs per year; 1 tubing failure or 3 rod failures; and 1 failure per year.

Other Methods

One operator reported use of surface equipment inspection. This is based on the limit that a pH of 6 or less is corrosive.

Equipping Wells

Flowing Wells

Forty-nine chemical injection valve installations were reported. Of these, nine experienced mechanical trouble, no records were kept on one, and one was not in use. Only two operators reported difficulty in obtaining a clean annulus as a reason for disliking injection valves.

Injection Valves. Five operators reported use of chemical injector valves in the tubing string to permit injection of chemical via the casing. One operator reported an installation in which the valve had given trouble by sticking in the open position. He added, however, that the valve was working successfully at the time the questionnaire was returned.

One operator, with two installations, reported a failure caused by plugging with mud, scale, etc. This operator expressed the present evaluation of the valves as poor. Another operator, with 16 installations, reported mechanical trouble in four installations. The trouble occurred when drilling mud and hardened chemical treating agent plugged the orifice ports. The fifth operator reported 30 installations. Of these, three were unsuccessful and one had not been placed in service. Two failures were caused by plugging. The third failure occurred because the valve was installed with an excessively high opening pressure. The operator was very well pleased with this method of chemical treatment.

Sidedoor Chokes. Three operators reported use of sidedoor chokes or perforated tubing as a method for injecting chemical via the casing in oil wells. One of these operators reported successful use of this method in gas wells and indicated that he planned to use it on oil wells in the future. One operator reported use of chemical injection valves in six permanent-type well completions. All three operators indicated that this method offered a practical means of treating high-pressure flowing wells. Their experience to date indicated success.

Tapered Tubing. One operator reported use of tapered tubing strings to relieve velocity effect. This method was used successfully in one field in high-pressure high-volume wells. Three operators reported use of three-inch tubing in high-volume gas lift wells.

New Equipment. New, special, or unusual equipment reported to facilitate chemical injection included the following:

1. Two operators attempted to use a free bottom hole chemical injector cylinder. This was not successful. Both operators expressed the opinion that ideal circumstances must be present for the tool to be efficient.
2. One operator tried using ¾-inch tubing as sucker rods to permit chemical injection. This failed because fatigue occurred at joints.
3. Small tubing has been used successfully to permit treatment by liquid inhibitor at the bottom.
4. In two installations liquid chemical has been forced into the bottom of the well through 3/16-inch macaroni tubing strapped to 2½-inch tubing connected by a fitting to the bottom joint of tubing. These installations have been used successfully for 14 months. Danger of crushing the small tubing and time required to run the combination tubing string are disadvantages of this method.
5. Chemical was forced to the bottom through a tail pipe run below the pump to protect the casing in one field.
6. One operator used a "bottom hole dump bailer" to make sure the concentrated chemical inhibitor or stick inhibitor was placed on bottom.

Gas Lift Wells

Use of insulated gas lift valves was reported by two operators. One of these operators used insulated valves in only one well. The value of the insulating bushing was not determined because the mandrels were plastic coated.

The other operator reported use of insulated gas lift valves had been established as standard practice on the Texas Gulf Coast. Here the need for insulated valves was indicated because of the considerable galvanic corrosion encountered on gas lift mandrels. This corrosion was attributed largely to the bi-metallic cell created by monel valves in contact with steel mandrels. The bi-metallic cell effect was verified by bottom hole coupon tests set up to simulate gas lift valve conditions. This operator reported combating galvanic corrosion by use of insulating valves has been used successfully for three years.

The majority of operators reporting did not consider galvanic corrosion to have been of much consequence. This was especially true of galvanic corrosion on the exterior of gas lift mandrels. The

greatest trouble was from corrosion-erosion occurring on the interior of the mandrel.

Seven operators reported successful mitigation of external corrosion and internal corrosion-erosion by coating mandrels inside and outside. Coatings reported as successful were baked-on phenolic, baked-on modified phenolic, ceramic and amine-cured air-dry epoxy. The baked-on phenolic was the coating most widely used. One operator reported use of this material successfully for four years.

Stress zone corrosion, created by welding lugs on the mandrel, was combated by several operators by stress relieving and heat treating the mandrel after welding.

To prevent loss of mandrels from abrasion one operator coated the zone between mandrel lugs. This coating consisted of two servings of ten-mil fiberglas set with Episeal resin.

Pumping Wells

Lubricators. Lubricators for injection of chemical in pumping wells was reported by a majority of operators. The use of beam and gas driven type chemical pumps also was reported. The latter was reported by only a few operators.

One operator reported that considerable maintenance was required on gas driven pumps. This operator found that use of pumps in Illinois was being discontinued because the inhibitor tended to collect in the top of the casing. Lubricator types reported varied from pipe nipples, shop or field fabricated lubricators to 55 gallon drums. Some operators reported using truck mounted chemical pumps for batch treatment.

Special Alloys. Sucker rods of special alloy material were used by several operators. Alloys were found to vary in composition to fit certain corrosive conditions. Use of special alloy and noncorrosive material parts for subsurface pumps was reported. Some operators indicated some of these materials were used to combat abrasion as well, if not more than, corrosion.

One operator expressed the opinion that the cost of special material for pumps and rods could not be justified on the basis of corrosion. At the time the questionnaire was returned he was conducting tests to see if his belief was correct. Another operator reported chrome or high alloy pump parts were not used where galvanic corrosion was encountered. Proper chemical treatment rather than use of special materials seemed to be the method most prevalent for combating corrosion in pumping wells.

Special Tubing Material (Without Chemical Treatment)

Plastic Coated Tubing

Of the ten operators who reported use of plastic coated tubing, eight reported the number of strings in service. This amounted to approximately 125 strings. Materials being used were: baked-on phenolic, baked-on epoxy-modified phenolic, air-dried vinyl, polyvinylidene chloride, a baked-on polyvinyl chloride, and an amine-cured, air-dried epoxy.

The only two strings coated with baked-on polyvinyl chloride failed. Two strings coated with baked-on phenolic failed as did one string coated with air-dried vinyl and one string coated with polyvinylidene chloride. One string coated with air-dried epoxy failed because of poor surface preparation.

The majority of the operators using plastic coated tubing did not consider that their installations had been in service long enough to allow good evaluations. One operator, however, reported that two strings coated with baked-on phenolic installed in 1952 were inspected 18 months later and were found free of corrosion. By January 1955, 20 additional coated strings had been run in this field. At that time two strings on baked-on modified phenolic coated tubing were put on test. This operator decided to use coated tubing in all wells in this field making over fifty percent salt water. The program will involve installation of more than 150 strings of coated tubing in wells predominately gas lifted.

The operator who installed approximately 60 percent of the coated strings reported indicated his present opinion of coating on test was good. He did not report, however, how long the coatings had been in service. At the time this report was prepared he was using baked-on phenolic, backed-on epoxy-modified phenolic, and amine cured air-dried epoxy.

One operator reported satisfactory service of baked-on phenolic coated tubing in gas wells. He also reported satisfactory use of the coating in 294 wells for paraffin. One other operator reported use of partial strings of coated tubing in four wells for paraffin.

Susceptibility to mechanical damage was the only objection given to plastic coatings. This is the factor that usually determines the life of the string.

Special Alloy Tubing

Seven operators reported using special alloy tubing. Alloys reported were: twenty-one strings of nine percent nickel, two strings of five percent nickel, one string of three and one-half percent nickel, and three strings of nine percent chromium. The information presented on nine percent nickel tubing in respect to water production was insufficient for conclusions to be drawn.

One operator felt that while nine percent nickel tubing was an excellent alloy for corrosion control its cost would make its use prohibitive except under extreme corrosive conditions or at isolated locations. He reported four installations of nine percent nickel strings.

Another operator reported that one string of nine percent nickel tubing had given good service for six years in a high pressure well making 65 percent salt water. He considered this to be an exceptional case that ran contrary to expectations. An operator reporting ten nine percent nickel strings considered the material unreliable because it had been found to be susceptible to stress corrosion cracking in high pressure wells after two to three years service. A caliper survey indicated 26 percent wall thickness penetration in a nine percent nickel string installed in a well producing water for six months. The string had been

in service for three years before the well began to produce water.

In another case an operator reported five strings of nine percent nickel tubing in service for six years with a wall penetration of only 16 percent. Only one of these wells produced salt water.

Use of five percent nickel tubing was not reported to offer any advantage. The three and one-half percent nickel tube experienced accelerated attack.

The operator reporting on the nine percent chromium tubing indicated no corrosion failures had been experienced. He added, however, that the material was not resistant to high chloride concentrations.

In reply to the question "Do you think special tubing materials should ever be used in preference to chemical treatment?" 13 out of 14 operators replied that special materials should be used. The majority qualified their affirmative reply by stating that special material and/or coated tubing should be considered for deep high-pressure wells with high fluid levels, in high volume flowing and gas lift wells where chemical treatment is expensive, or in wells located in isolated places. One affirmative reply stated a preference of coated tubing over chemical treatment.

The single negative answer stated that special material was not, at this time, as economical as chemical treatment.

Chemical Treatment

Liquid Inhibitors

Organic inhibitors were being used by all operators that reported use of chemical treatment for corrosion inhibition. Only two operators reported the use of liquid inorganic inhibitors. Of these one offered no details and the other reported that an inorganic inhibitor was under test in a well where both scale and corrosion were to be found.

Organic inhibitors of practically all known manufacturers were reported in use. Reasonably satisfactory results were reported for all organic inhibitors. It was indicated that chemical treatment of gas lift wells had not been as satisfactory as most operators would like it to be. This was particularly true in treating the portion of tubing string below the operating valve.

The batch treatment method of chemical treatment was favored by the majority of operators. Several, however, used both the batch and continuous treatment methods and a few used only the continuous treatment method.

All but one operator reporting used inhibitors as normally supplied or diluted to varying degrees with water or oil. The other operator reported use of concentrated inhibitor. The amount of chemical reportedly used to treat wells varied from 6-100 ppm and 1 quart per day to 2-3 gallons per week. Only a few operators reported the cost of treatment. The cost reported varied from 4 mils/barrel to 3-5 cents/barrel of oil produced and from $6.50 per treatment to $30.00-$45.00 per month.

Weighted Inhibitors

Use of weighted liquid inhibitor was reported by three operators. Results indicated successful use of weighted inhibitors in high fluid level pumping wells, high gas-oil ratio flowing wells and high fluid-level gas-lift wells. One operator remarked that use of weighted inhibitors had been curtailed because the chlorinated solvents used for weighting caused dangerous corrosion and process upset in platformers at the refinery. He reported that the weighted inhibitors show improvement over the unweighted.

Stick Inhibitors. It was found that most operators were using stick inhibitors on a limited basis. The devices were used to treat wells in isolated areas where flowing wells were set on a packer and on some high fluid-level gas-lift wells. They were used also in cases where liquid chemicals would not protect the well. In addition to this it might be mentioned that they were for certain special purposes such as treating gas-lift wells in conjunction with liquid inhibitors to ensure treatment of the tubing below the operating valve and to precede a caliper survey to protect areas scratched by the caliper.

The main objection to stick inhibitors is that sometimes they stick and the operator can not always be sure they get to the bottom. Treating with stick inhibitors is more expensive than treating with liquid inhibitors. A comparable cost quoted by one operator was $1.15 per well per day using stick inhibitors and $1.04 per well per day using liquid inhibitors.

Pellet Form Inhibitors. Two operators reported use of inhibitors in pellet form. One of these reported use of a slow melting and dissolving pellet in pumping wells. This practice has not been in use long enough to allow conclusive analysis. The other operator merely stated inorganic pellets were being used in high water log wells.

Inhibitor Choke. Sixteen operators replied to a question on the highly controversial subject of whether to use an oil-soluble or water-soluble inhibitor in relation to percentage water produced. The replies were as follows: eight preferred water-soluble inhibitors for wells producing a high percentage water, three preferred oil-soluble, two indicated the choice depended on the height of the fluid column, and two preferred an inhibitor in a dispersed state rather than a dissolved state. One operator said he did not know which was preferable.

Treatment Period. All operators using organic inhibitors indicated the inhibitor provided some lasting effect. The extent has not yet been determined. The treatment period trend seemed to be toward batch treatment with treatments ranging from once a day to once every three weeks. Most operators reported that one week was the longest period between treatments.

It was thought that the volume of fluid produced had a great deal to do with the extent of effect. One operator reported that a well making over 1000 barrels per day should be continuously treated. Results

from batch treatments were said to be good. Operators reported they had been able to lengthen the time between treatments or cut down on the amount of chemical used per treatment after the initial treatment stage.

Answers were evenly divided to the question "In pumping wells, is circulation of well fluids practical with batch treatment?" The reason advanced for circulating was to ensure that chemicals got to the bottom. Hence, the choice becomes a matter of economics inasmuch as the results must be weighed against the expense of chemical, labor, and well shut down time. Some operators reported they circulate on initial treatment to ensure immediate protection.

Special Techniques. The specific technique of using a "bottom hole dump bailer" for treatment of high fluid level wells was discussed earlier in the report. The operator using this technique had one bailer designed for concentrated liquid inhibitor and one for stick type inhibitors. Both bailers were operated from a truck equipped with a wire line and wellhead lubricator. The main advantage of the dump bailer is that the element of doubt as to whether the inhibitor is getting to the bottom of the well is removed.

Two operators reported use of a new method of treating wells which may be used regardless of fluid level. The method employs the unique technique of squeezing an organic-absorptive type inhibitor back into the formation.

One operator who has treated seven wells with this technique squeezed 55 gallons or more of inhibitor into the formation with a small pump (10 gallons/minute) followed by 45 to 60 barrels of brine. The well was allowed to stay shut-in for approximately 12 hours and then was placed back on production as usual. A considerable reduction in iron content has been achieved by using this manner of treatment. The technique was started in November 1954. The operator reported each squeeze job gave protection for three to six months depending upon the amount of fluid produced by the well. He said the technique has the following advantages:

1. All metal in the well that comes in contact with the produced fluid receives chemical treatment.
2. The technique provides a more continuous supply of chemical in the well fluid.
3. The technique is more economical than daily batch treatment. The cost of squeezing a well using 55 gallons of chemical is approximately $150. The average daily treatment cost, using the squeeze technique, is $1.25. The cost using the daily batch treatment was $2.30.

The technique reported by the other operator was to squeeze 55 gallons of organic inhibitor mixed with three barrels of oil back into the formation. This is followed by six barrels of oil. Only one well was treated in this manner. The technique was evaluated by use of iron content, surface, and sub-surface coupons. The iron content and surface coupons have shown only a slight increase in corrosion rate to date. Sub-surface coupons indicated protection was obtained for 60 days.

Some operators indicated they used chemical treatment to a minor degree with coated tubing. Some expressed the opinion that coated tubing might require chemical treatment if the coating were damaged and bare metal exposed. It was hoped, in those cases, that a reduced amount of inhibitor would be sufficient for protection of the exposed bare spots.

No operators reported use of chemical treatment with special alloy tubing. The majority expressed the opinion that this material would not require chemical treatment except under extreme corrosive conditions.

Determination of Effectiveness of Chemical Treatment. Five of the twelve operators using iron content considered it the best method for determining the effectiveness of chemical treatment. The other seven considered iron content to have comparative value and to be a valuable tool when used in conjunction with other methods.

Nine operators reported using coupons in determining the effectiveness of chemical treatment. Surface coupons were used mainly as a comparison or double check with other methods. One operator reported widespread use of surface coupons to be a good indication of corrosive conditions. Surface coupons are of no value in fields that produce sand. One operator reported using subsurface coupons in two fields. This operator considered them to give the best indications next to the caliper survey to the effectiveness of chemical treatment.

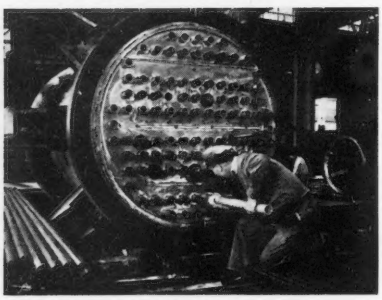
All operators that used the caliper survey considered it to be the best method available for locating and determining the magnitude of corrosion in tubing and determining the effectivenes of chemical treatment. The main objection to this method was the expense involved.

All operators considered extended equipment life to be the most indisputable indication of the effectiveness of chemical treatment. Three operators reported this was the only method they used. This is the method in which management is most interested.

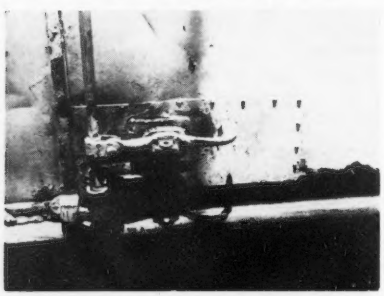
One operator reported using lifting cost in dollars per barrel as a method of determining the effectiveness of chemical treatment. By properly controlling corrosion, the lifting cost could be reduced. In order to control corrosion, economics must be placed first.

One operator reported using visual inspection of down hole equipment during well servicing as a method for determining the effectivenes of chemical treatment. This was supplemented by non-destructive testing and visual inspection of surface equipment.

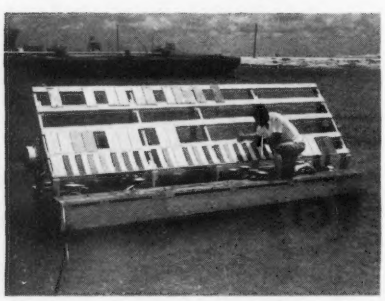
Control by Heat Treatment



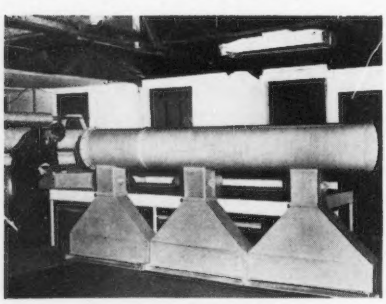
Control by Material Selection



Control by Correct Design



Control by Service Testing



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Status Report of NACE Technical Unit Committee T-1J On Oil Field Structural Plastics*

THIS REPORT summarizes the activities of Technical Unit Committee T-1J on Oil Field Structural Plastics subsequent to the committee meeting held in Chicago, Illinois on March 11, 1955. This along with other status reports of T-1J published in the Technical Committee Activities Section of *Corrosion* are designed to keep the membership of NACE up to date on the activities and findings of the committee. The report previously has been submitted to and approved by Group Committee T-1 on Corrosion in Oil and Gas Well Equipment.

Abstract

Long term strength of cellulose acetate butyrate is discussed. The strength of the material had been reported previously to be near 800 psi at about 100 F. Recently another investigator found the value to be around 400 psi by a similar test. Reasons for the difference are discussed and explained by the company making the first report.

A report on service experience of plastic tanks is given. This supplements a report on this subject published in 1955. Cracking type failure is believed to result from eccentric loading that comes from filling and emptying the tank. The cracks generate from irregularities or wrinkles in the glass. If the theory is true, cracking type failure can occur with tanks fabricated from any resin system and probably can be eliminated only by careful glass handling and control by the tank fabricator.

New Committee Project-Survey of Extruded Plastic Pipe

T. M. Yeiser, Crescent Plastics, Inc., Evansville, Indiana and R. J. Perkins, Southwestern Plastic Pipe Company, Mineral Wells, Texas have been assigned as a Task Group of two to draft a questionnaire to cover the subject of an extruded plastic pipe survey. The general approach will be such that a summary of replies should indicate how users presently feel about extruded plastic pipe. Some questions suggested for the questionnaire are as follows:

1. Do you presently use extruded plastic pipe as a standard item for service such as low pressure flow lines and salt water disposal lines? Yes.... No.....
2. If the answer to Question 1 is yes, about how much footage of pipe have you used in 1955. .....
3. If you used any extruded plastic pipe in 1955, please give the number of failures that were attributed to:
   a. Excessive pressure.....
   b. Excessive Temperature.....
   c. Poor glue joints.....
   d. Poor installation method.....
   e. Impact blow.....
   f. Faulty pipe manufacture.....
   g. Other.....
   h. Total failures of pipe installed in 1955.....
4. If you do not use now, or have never used extruded plastic pipe, which of the following reasons do you feel are responsible for this policy within your company?
   a. No field experience by our company or nearby operators.....
   b. No low pressure applications.....
   c. Attempted a few field installations with poor results.....
   d. No contractor familiar with installation methods.....
   e. Insufficient physical data for safe design methods.....
   f. Estimated installation cost offered little savings.....
   g. Other.....
5. If you do not use, or use only a small amount of extruded plastic pipe, what type of information would allow your company to consider and possibly use the material?
   a. Performance and specific operating data on past installation.....
   b. Pipe operating pressures for a reasonably well established and published safety factor.....
   c. Installation costs.....
   d. Other.....

Long Term Strength of Styrene Copolymer

Almost from its inception T-1J has made an effort to obtain long term strength data concerning plastic pipe and tank materials. In line with this committee objective a member of the committee has presented a report on long term strength styrene copolymer pipe and strips. Although the material does not appear to creep under stress, its useful life depends on stress and temperature. The member's work indicates a stress of 1,550 psi can be tolerated for a one-year life, 1,370 psi for five years and 1,300 psi for ten years. Based on these findings, the Society of the Plastics Industry has recommended to the American Gas Association the following maximum stress levels:

1,200 psi at 73 F.
1,000 psi at 100 F.

It is expected the report will be published as a report to Unit Committee T-1J in the near future.

Glass-Reinforced Plastic Pipe

The committee has received a report that two manufacturers of glass-reinforced plastic pipe have recently installed test sections for service at high pres-

*B. W. Bradley, Shell Oil Company, New York, N. Y., chairman.

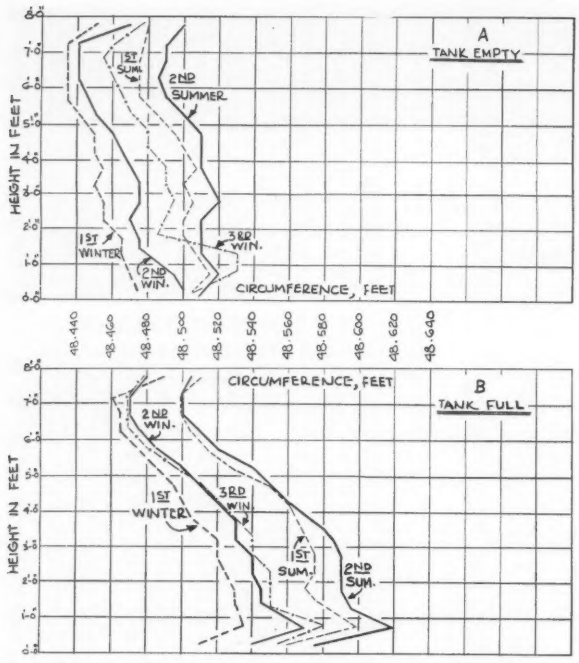

Figure 1—Circumferential measurements of glass-polyester stock tank.

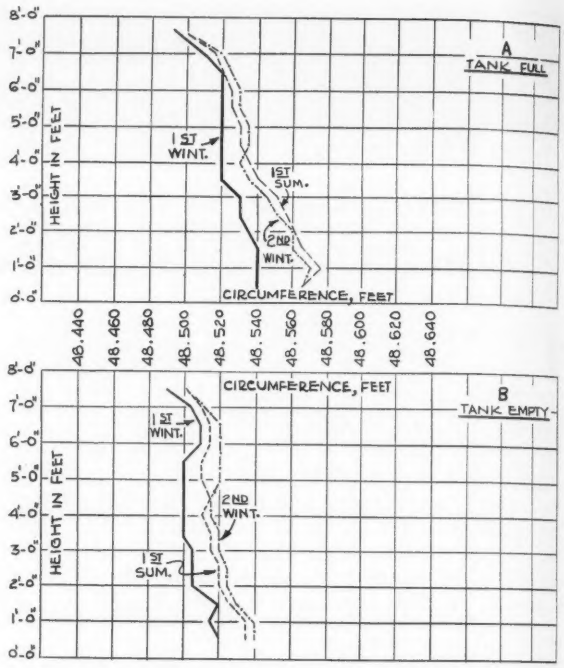

Figure 2—Circumferential measurements of glass-epoxy tank.

sures with several oil operators. Although experience is as yet limited, there are indications of general success. Representatives of both manufacturers have agreed to summarize these installations at the T-1J meeting scheduled during the 1956 NACE Annual Conference in New York, March 12-16.

Long Term Strength of Cellulose Acetate Butyrate

In 1954 it was reported to the committee that the strength of cellulose acetate butyrate was near 800 psi at about 100 F. Subsequently another investigator, using a similar test, found the strength of the material to be around 400 psi at approximately 100 F. The research organization of this investigator found that one piece of butyrate pipe had a rapid strain rate after 30 weeks at 460 psi stress and 110 F. One explanation for the difference in strength was that reground plastic may have been used.

Application to the weaker pipe of the data originally reported to the committee could only result in failure. An inquiry was directed to the company that made the original report asking if they could undertake tests on numerous commercial plastic pipes manufactured from the two sources of plastic. It was suggested that while variations other than the resin might cause such differences, virgin and reground plastic probably would cause a more significant difference in pipe strengths than other manufacturing variables.

To further confuse the issue the manufacturers of the weaker pipe claimed their product had an "effective strength" of 1500 psi at 110 F, and recommended a maximum operating stress of 630 psi. It is obvious from tests made that both of these values were above the long-term strength of the material.

The manufacturers of the pipe originally reported on were asked to present their thoughts on the matter. This was done because the later tests forced users to use a maximum design stress of something less than 460 psi at 110 F rather than 740-935 psi the first study indicated. This would be necessary in order to protect the user from premature failure when using the pipe concerned.

In answer to the inquiry the company answered they were surprised to hear about the lower hoop stress figures on butyrate pipe. They further stated that ASTM Committee D-20 was preparing specifications for plastic pipes. The requirement for the base material was to be included in these specifications. The proposed specification for butyrate was to be D707-51T Type 1 designation MH-3. The test methods under consideration included pressure tests, impact, stress relief and ductility. They were to be conducted by the pipe manufacturers and consumers for identification tests.

The tentative procedure for the stress relief test is to determine the percent shrinkage of the pipe specimen at 270 F for 30 minutes. The allowable shrinkage has not been decided upon by ASTM; however, data indicate the allowable shrinkage should be less than 5 percent.

It is common knowledge that best test results can be obtained from pipe with a minimum amount of internal stresses. This program should be a progressive step encouraging the use of quality pipe for industrial applications. It will benefit the end user as well as the extruder and manufacturer. It is also felt that these tests should be given to pipes used for test purposes in obtaining engineering data such as creep tests. This will help to screen substandard material.

The use of reground material creates difficulty when the physical properties of extruded pipe are

projected. This is true when efforts are made to obtain reliable data for reproducible results. Frequently, molded objects made from substandard reprocessed material may be brittle or not as tough as objects made from virgin material. Extruded pipe is an even more critical application because it will be subjected to more structural stresses.

Possibly the lower hoop stress value was obtained from a softer flow material than that used as the basis for the higher strength data. It is possible that the composition of the reground material may have unknown formulas and different flows from regular pipe material. This may have affected the extrusion conditions and physical properties.

Other variables which may cause a lower hoop stress are as follows: nonuniform wall thickness (weak spot), accidental increase of pressure and/or temperature during the creep tests, inaccurate test gauges (these should be checked occassionally), poor extrusion technique producing inferior pipe and bad weld lines. A decision should not be based on one piece of data especially if it is obtained from a pipe made from reground material. Reground material added to virgin material would not be expected to affect the physical properties if it were of the same formula and flow, kept clean and not subjected to abnormal conditions during previous operations.

Service Experience of Plastic Tanks

This report supplements a report on service experience of plastic tanks included in the Status Report of T-1J published in the Technical Committee Activities Section of the June 1955 issue of *Corrosion*.

The curves in Figures 1 and 2 present a summary of strapping data on both glass-reinforced polyester and glass-reinforced epoxy tanks. The polyester tank was described by Reply 1 and epoxy tank by Reply 8 in the previous report. Figure 1 is a continuation of data given in Figure 4 of the previous reports; Figure 2 is a continuation of Figure 5. In both cases the figure numbers of the previous report refer to corrected values as given in the errata sheet (*Corrosion*, 11, 62, (1955) Aug.)

Glass Polyester Tank

Figure 1 shows the circumferential measurements of a glass mat reinforced polyester, 250-barrel tank, both empty and full, during three winters and two summers. By comparing the full measurements during the second and third winters, it can be seen that creep of the laminate during the last year was less than between the first two winters. Comparison of the empty measurements during the second and third winters indicate the tank has been permanently deformed by the service. This deformation was about the same as occurred between the first two winters except for the bottom two feet of the tank. In that area, where the highest stress occurs, the service apparently caused more enlargement than noted during the first year.

Although difficult to see in Figure 1, it is of interest to note that the average increase in circumference between empty and full during both summers and the first two winters was about 0.050 foot, whereas, it was only 0.032 foot on the third winter measurement. This may indicate the material is approaching the limit of expansion caused by hoop stress.

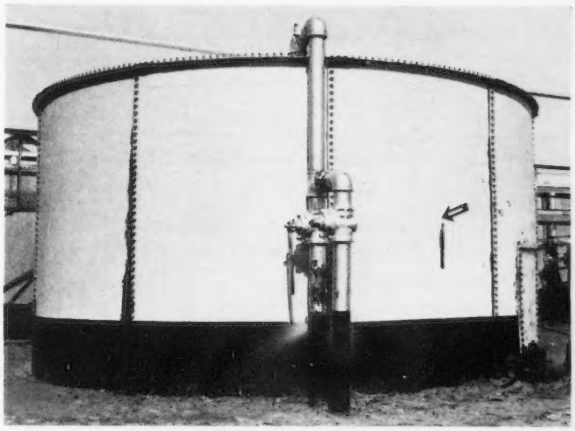

Figure 3—Glass reinforced polyester tank. Note cracks at arrow.

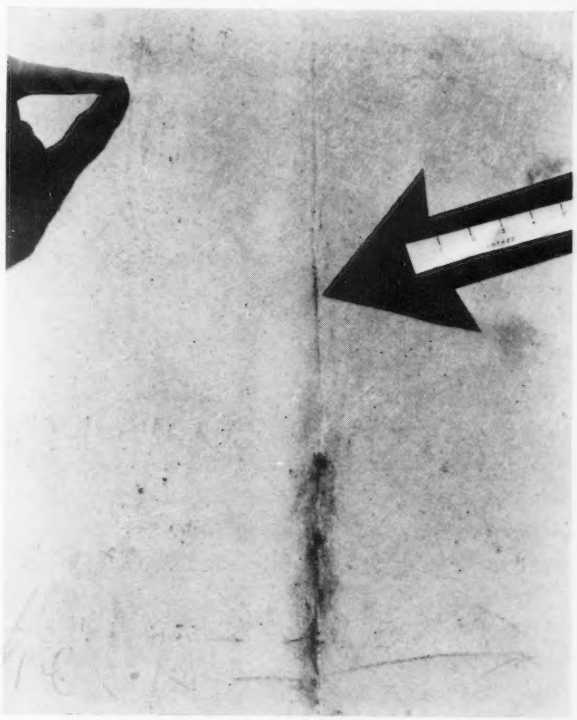

Figure 4—Closeup of cracks shown in Figure 3.

Glass-Epoxy Tank

Figure 2 shows the circumferential measurements of a glass roving reinforced epoxy, 250-barrel oil-field stock tank during two winters and one summer.

In this case it can be seen that the measurements, both empty and full, during the second winter are similar to those obtained during the first summer. Inasmuch as the second winter measurements should have eliminated difference caused by temperature effects, this laminate may be approaching the limit of deformation to be caused by service conditions.

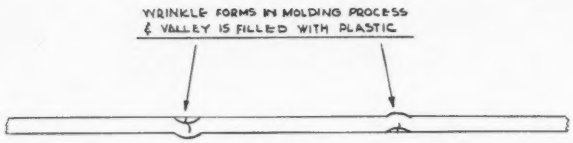

Figure 5—Cross section of stave showing relation of wrinkle in glass and crack.

The average difference in circumference between empty and full conditions has been about 0.018 foot on all three measurements.

Cracking Type Defect

A report describing a cracking type defect is discussed below. This type defect could occur in any laminate. This tank was described by Reply 3 in the previous report.

This glass-reinforced polyester, 250-barrel tank was erected during November 1952 for stock-tank service. An inspection in early 1955 revealed four cracks. These were externally visible. Numerous cracks were seen to be forming on the inside. As shown in Figure 3, the failure (indicated by the arrow) occurred in a vertical direction 26 inches from a bolt row. Figure 4, a close-up of the crack, illustrates the feather edge appearance of the hairline failure. An irregularity or wrinkle in the glass is shown in the upper left corner of the photograph. It is believed these wrinkles as shown in Figure 5 in the reinforcing glass are the cause of highly stressed zones of resin.

Because the highest tensile-stress variation occurs at the inside of the fold, eccentric loadings resulting from emptying and filling the tank are believed to cause fatigue cracks to generate from the valleys to the crest of the folds. If this theory is true, cracking-type failure can occur with tanks fabricated from any resin system and probably can be eliminated only by careful glass handling and control by the tank fabricator.

Following the inspection, it was necessary to replace the clean-out plate because of a similar failure. The crack in the plate existed over the complete length and allowed considerably more leakage than shown in Figure 4.

New Meter Designed for Cable Sheath Testing

High Accuracy at Low Amperages Is Principal Asset

Design of a zero resistance ammeter for measuring currents on cable sheaths in the range 2 milliamperes to 10 amperes has been completed. The circuit was completed by Project Group T-4B-3B on Measurement of Current Flow on Cables. On currents as low as 20 milliamperes accuracy is 75 percent over 18 inches of cable sheath about two inches in diameter.

The need for such a circuit became evident during discussions of Task Group 4-B-1, most recently at Niagara Falls in October, 1955. The need for an instrument accurate enough to measure current loss between manholes in non-stray current areas was discussed at that meeting, among others. During the consideration of the problems involved in measuring currents of such low magnitude both power company and telephone company engineers cited need for an accurate instrument. Power companies, for example, experience drops as a consequence of thermoelectric potential differential cells, one company reporting drops in the vicinity of two milliamperes.

Completion of the design for the circuit was announced in the January status report of T-4 on Utilities to C. P. Larrabee, chairman of the Technical Practices Committee. Engineers familiar with the difficulties associated with potential measurements near zero are reported to believe the new circuit will be very useful.

Other matters discussed at the October meeting of T-4B-1 include:

Project Committee T-4B-1A

This group has completed a report entitled "Cell Corrosion in Lead Cable Sheaths" which will be considered for approval in the near future.

Project Committee T-4B-1C

Sufficient evidence has been reported by members of this committee to indicate that an investigation of corrosion by alternating currents may be justified.

Other Items Covered

Among other significant informatioon included in the January report by F. E. Kulman, chairman of T-4 to Mr. Larrabee was:

A final report is in preparation and scheduled for presentation in March on the tests conducted on neoprene and polyvinyl chloride cable jackets. This is an activity of Task Group T-4B-5 on Non-Metallic Sheaths and Coatings, G. H. Hunt, chairman.

Pipe Wrappings Tentative Specifications Readied

Tentative Specifications for Glass Wrapper and Asbestos Felt wrapping for pipe underground probably will be presented for discussion at New York. The subject is on the agenda for the meeting during the 12th Annual Conference at Hotel Statler, New York of Unit Committee T-2J on Wrappers for Underground Pipe Line Coatings.

Third Report on Cable Sheaths Is Completed

The Third Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths has been completed and is being processed prior to publication. The report, which digests the answers to five questions concerning utilities' practices in controlling cable sheath corrosion by cathodic protection, is in the same general area of information as two published earlier.

The current compilation by Task T-4B-2 on Cathodic Protection of Cable Sheaths covers answers from 30 companies. R. M. Lawall is chairman of the group. Numerous engineering drawings submitted in answer to the questions also are scheduled to be included in the report.

Questions asked in the original and a supplemental questionnaire pertained to:

1. Rules relative to maximum allowable cable-to-earth potentials and special methods to avoid cathodic corrosion.
2. Rectifier ground bed design and location.
3. Installation of galvanic anodes.
4. Rectifier characteristics.
5. Use of insulating joints.
6. Use of protective coatings.

•

Technical material published in Corrosion is abstracted in the biennial Bibliographic Surveys of Corrosion published by NACE.

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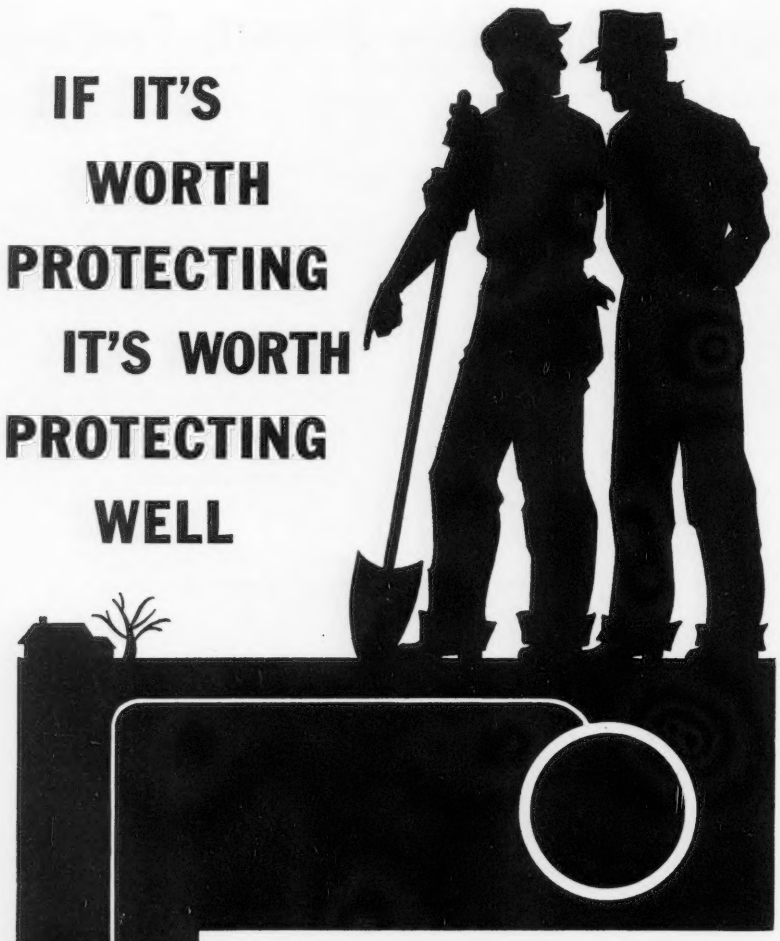

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E. J. Nicholas Now Heads Railroad Committee

L. J. Nicholas, The Pullman Company, Chicago has been elected chairman of Unit Committee T-3E on Railroads. He is presently occupied in research leading to mitigating corrosion on Pullman sleeping cars as a member of his company's Bureau of Tests.

Nicholas

A graduate of University of Illinois with a BS in chemistry in 1950, he did graduate work in chemistry at Bradley University while on a chemistry assistantship during 1950 and 1951. Besides NACE he is a member of the Sea Horse Institute.

Final Reports Are Ready On PVC, Epoxies, Rubber

Final reports by Committee T-6A on Organic Linings and Coatings for Resistance to Chemical Corrosion have been completed on rigid polyvinyl chloride, epoxy resins and chlorinated rubber coatings. R. McFarland is chairman of the committee. These three reports are scheduled to be published in the April issue of CORROSION.

Rigid Polyvinyl Chloride—This report covers average properties of Types I, II and III (SPI designations). Resistance of the materials versus several common classes of corrosive materials, data on fabrication as well as resistances to specific concentrations of some corrosives are included.

Epoxy Resins—Use and summary of average properties and resistances by classes and to specific corrosives are given.

Chlorinated Rubber—Use and summary of average properties are given, forms listed, compounding effects detailed and resistances to specific environmental conditions covered. Properties of applied coatings and linings are covered as are priming and application methods. Tables of resistances to specific corrosive solutions at two temperature levels are included.

Cast Iron Anode Report Prepared for New York

Progress on collection of data pertaining to installations of cast iron anodes in cathodic protection ground beds is expected to be reported at New York during the March Conference. A group on this topic was named by T-2B on Anodes for Impressed Currents and will report at this committee's meeting.

A report on the work of the committee's task group on Rectifiers for Impressed Current Anodes which has been cooperating with a group from the National Electrical Manufacturing Association is expected to be considered also at the March meeting of the group.

The committee also has taken under consideration the study of the use of platinum, palladium and other precious metals for anode use.

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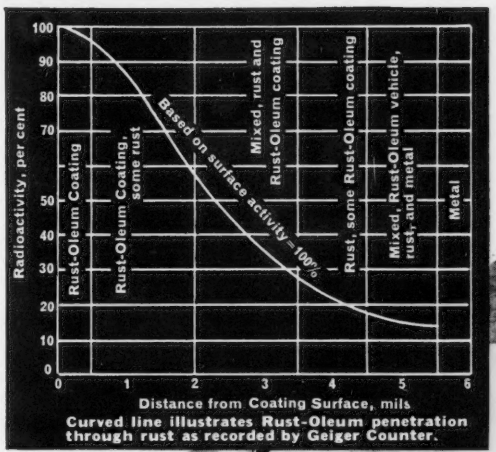

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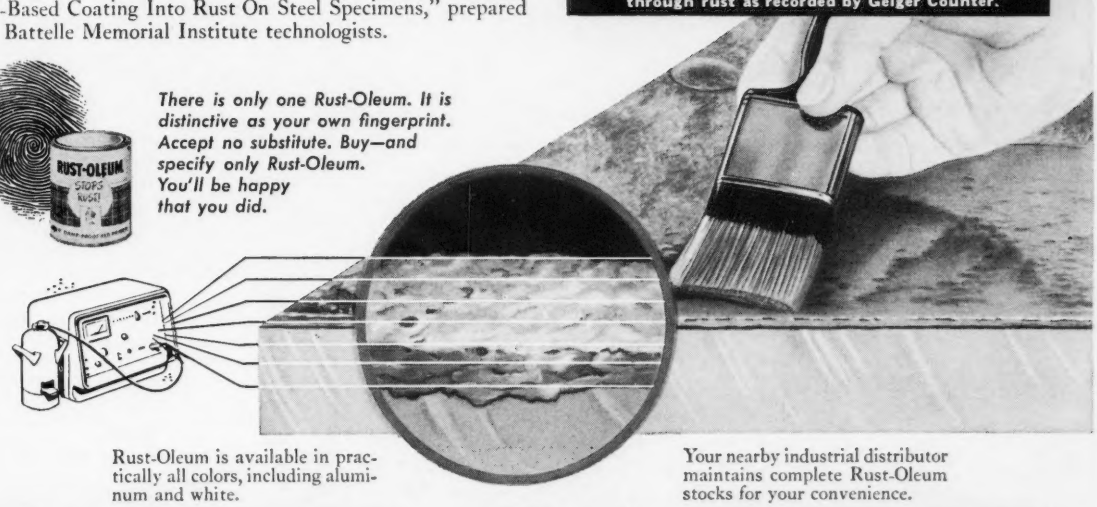

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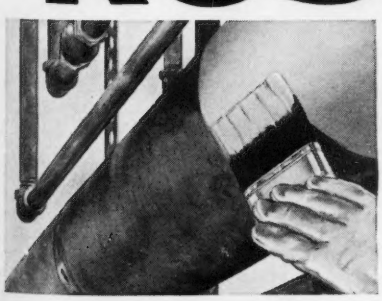

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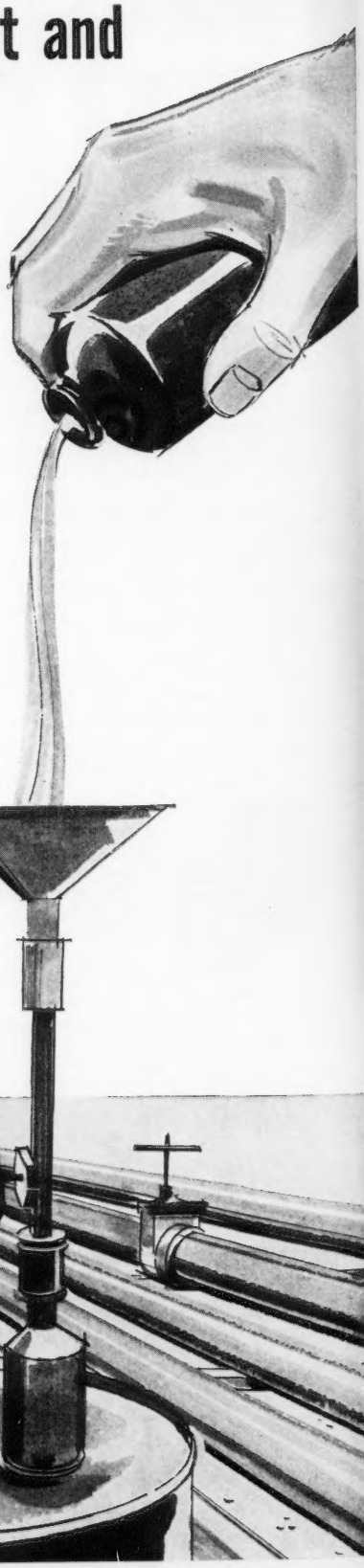

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NACE NEWS

Buffalo Sessions Focus on Chemical Industry

MONTERREY SHORT COURSE scenes: Top, one of the classes in session. At lower right holding microphone is translator, who translated English lectures into Spanish. Bottom, lecturers, top row: R. B. Bender, Plastic Engineering and Sales Corp., Fort Worth; Humberto Lobo, Jr., Fabricias Protexa, S.A., Monterrey, N. L., Mexico; W. F. Fair, Jr., The Koppers Co., Pittsburgh; W. H. Stewart, Sun Pipe Line Co., Beaumont, Texas; lower row: K. D. Wahlquist, Southern Union Gas Co., Dallas; H. V. Beezley, United Gas Pipe Line Co., Shreveport; Sidney E. Trouard, New Orleans Public Service, Inc.; T. F. P. Kelley, Mavor-Kelley Co., Houston.

May 9-10 Meeting Set by Niagara Section, Buffalo University

Control of Corrosion in the Chemical Industry is the theme of the May 9-10 meeting to be held at University of Buffalo, New York, with arrangements by Niagara Frontier Section National Association of Corrosion Engineers and the university.

Emphasis will be on the proper use of metals and alloys to prevent corrosion. The tentative program for the technical portion of the meeting has been arranged as follows:

Wednesday, May 9

Morning: Fundamentals of Metallic Corrosion by Milton Stern, Metals Research Laboratory, Electro Metallurgical Company, Niagara Falls, New York; Iron-Base Alloys by S. H. Kalin, Applied Research Laboratory, United States Steel Corporation, Monroeville, Pennsylvania.

Afternoon: Stainless Steels by C. P. Dillon, Carbide and Carbon Chemicals Company, Union Carbide and Carbon Corporation, Texas City, Texas; Copper and Nickel-Base Alloys by H. O. Teeple, The International Nickel Company, Incorporated, New York.

Thursday, May 10

Morning: Aluminum and Magnesium Alloys by H. P. Godard, Aluminium Laboratories, Ltd., Kingston, Ontario; Metallic Coatings, by W. W. Bradley, Bell Telephone Laboratories; Lead by Kenneth H. Roll, Lead Industries Association, New York.

Afternoon: Titanium, Zirconium and Tantalum by W. E. Lusby, Jr., E. I. du Pont de Nemours & Co., Inc; High-Alloy Materials by E. D. Weisert, Haynes Stellite Co., Div. of Union Carbide and Carbon Corporation, Kokomo, Indiana; Chemical Plant Problems by M. G. Fontana, Ohio State University, Columbus.

Monterrey, Mexico Corrosion Short Course Has 88 Registered

Registrants at the Corrosion Short Course given at Monterrey, Mexico February 1-3 visited a steel mill there at which 8 and 14-inch steel pipe was being made and the coal tar enamel plant of Fabricas Protexa. Registration for the course was 88. The course was given by Instituto Techologico y de Estudios Superiores de Monterrey with the cooperation of the National Association of Corrosion Engineers.

Some changes were made in the program as published in CORROSION, February issue, Page 72. H. V. Beezley, United Gas Pipe Line Co., Shreveport replaced G. R. Olson of the same firm in presenting the lecture "Corrosion and Cathodic Protection Simplified." The lecture "Plant Protecting Problems" was dropped from the program. Derk Holsteyn's paper "Cathodic Protection Within an Oil Refinery" was read by W. H. Stewart, Sun Pipe Line Company, Beaumont.

Thornton Heard at Dallas On Oilfield Plastic Pipe

Several methods of pipe manufacture and how they affect material used to fabricate plastic pipe for oil field service were covered in a talk January 9 before 42 members and guests of North Texas Section. W. M. Thornton, Atlantic Refining Co., principal speaker at the Dallas meeting also listed prices of commonly used oilfield plastic piping.

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More than 500 periodicals are canvassed for abstracts appearing in Corrosion Abstracts.

Electrodeposited Coatings Discussed at Cleveland

About 50 members and guests attended the January 17 meeting of Cleveland Section and the Electrochemical Society. W. H. Safranek of Battelle Memorial Institute spoke on Uses of Newer Electro Deposits in Combating Corrosion.

Plans are being made by the Cleveland Section to conduct a half hour television program on "Corrosion Engineering As A Career" later in 1956. Also planned is a three or four-day symposium to be held in August at Case Institute of Technology on Protective Coatings and Protective Linings.

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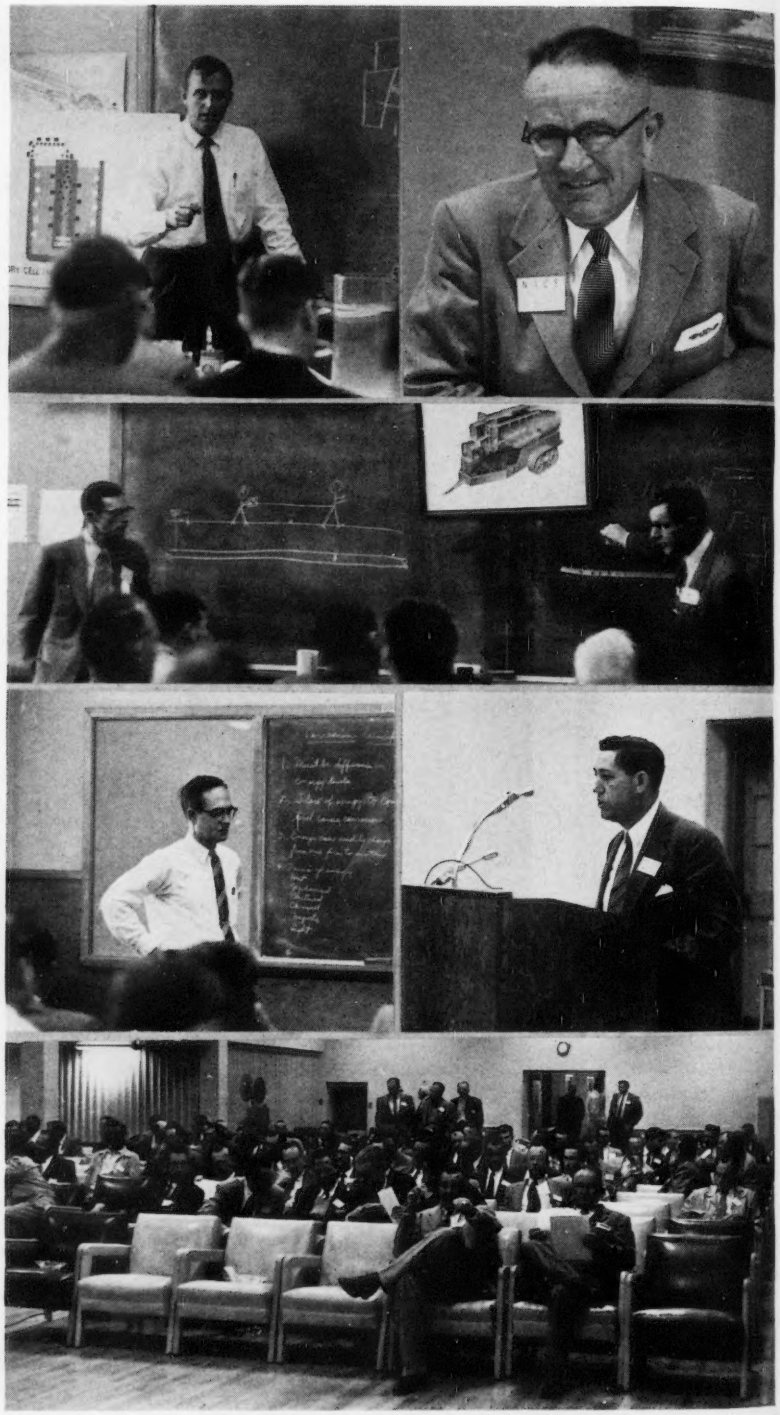

SEEN AT HOUSTON SECTION'S SHORT COURSE January 19-20 at University of Houston: Top, left, M. A. Riordan, Rio Engineering Co., discusses galvanic anodes; top, right, E. S. Murray, vice-president, Tennessee Gas Transmission Co., who made the welcoming address; second from top: L. G. Sharpe, left, Napko Paint and Varnish Co. and Maurice W. Belson, right, D. E. Stearns Co., Shreveport, conducts a class in coating inspection. Third from top, left: L. R. Sheppard, Shell Pipe Line Corp., conducts a class in corrosion principles; right, C. L. Woody, United Gas Corp., general chairman, explains the content of the course to registrants. Bottom: View of registrants, who numbered more than 85.

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More than 230 authors contributed to the Technical Section in Volume 11, Corrosion.

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More than 500 periodicals are canvassed for abstracts appearing in Corrosion Abstracts.

Sweet Oil Well Problems Covered by Greenwell At New Orleans Session

"Water dependent" and "water independent" sweet oil well corrosion were discussed by H. E. Greenwell, chairman of NACE's T-1C Sweet Oil Well Corrosion committee at a meeting of New Orleans-Baton Rouge Section. Mr. Greenwell, with Atlantic Refining Co., Dallas, spoke to 25 members and guests at the section's January 23 meeting.

Greenwell

Mr. Greenwell divided his discussion into two parts, one concerning the usual "water dependent" corrosion encountered in oil and gas wells and the other the little known, so-called "water independent" corrosion experienced in high gas-oil ratio, high pressure oil wells producing pipeline oil. He told of work being done by Atlantic in combating these corrosion problems and gave information gained through his work as chairman of committee T-1C.

Mr. Greenwell first related the usual methods of recognizing and combating water dependent corrosion including failure experience, water analyses, coupon exposures and caliper surveys for detection work; and inhibition, coatings and special metals for mitigation work.

In his discussion of water independent corrosion, Mr. Greenwell defined the mechanism by which such corrosion is believed to take place and the difficulty of discerning and alleviating it. Considerable interest was shown in this because of the number of offshore wells that may be affected by water independent corrosion and the high cost of remedial work on them.

In closing Mr. Greenwell expressed his own appreciation and that of Committee T-1C, for the opportunity to speak before the group. An interesting and informative question and answer period followed his lecture.

R. M. Robinson, secretary-treasurer of the section announced the February 27 meeting was scheduled at the New Orleans Engineering Club with Dr. F. J. Radd, Continental Oil Company to speak on "Corrosion Metallurgy of High Strength Tubing and Casing."

Electrodeposited Metals Are Discussed by Sample

Clarence Sample of the International Nickel Company, Inc., spoke at the January 17 meeting of the Genesee Valley Section at The Rochester German Club. Approximately 30 members and guests heard him discuss the Corrosion Resistance of Electro-Deposited Metals. He covered the electro-deposition of lead, zinc, cadmium and copper-nickel-chromium combinations, their applications and relative protection effectiveness. A discussion followed Mr. Sample's presentation.

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Indexes to Corrosion's Technical Section, Technical Committee Activities Section and Corrosion Abstract Section are published annually in the December issue.

Valve Stem Dezincification Is Topic at Los Angeles

Dezincification of Valve Stems in Water Service is the scheduled topic for the March 21 meeting of Los Angeles Section at Rodger Young Auditorium. C. E. Tabor, Dept. of Water and Power, City of Los Angeles, will be speaker.

The section heard Robert Brown and Ellis D. Verink of Aluminum Corp. of America's New Kensington, Pa. research laboratories speak on Aluminum for Corrosion Resistant Applications at its February 22 meeting.

The March 21 meeting also will feature installation of new officers.

Sabine-Neches Section Hears Copper Alloys Talk

Thirty-five members and guests attended the January 19 meeting of Sabine-Neches Section at which D. S. Neill of the Bridgeport Brass Company spoke on "Dezincification of Copper Base Alloys." Mr. Neill defined and illustrated the various types of dezincification commonly found in brass condenser tubes. The causes of dezincification as well as corrective measures were discussed. The mechanism of inhibition by arsenic was described.

"Corrosion Problems with High Speed Rotary Compressors," was to be the subject of the meeting scheduled for February 23.

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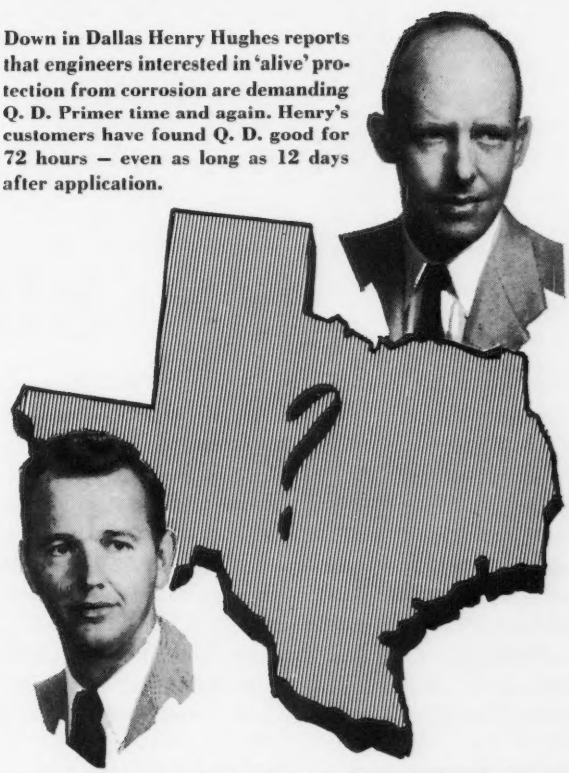

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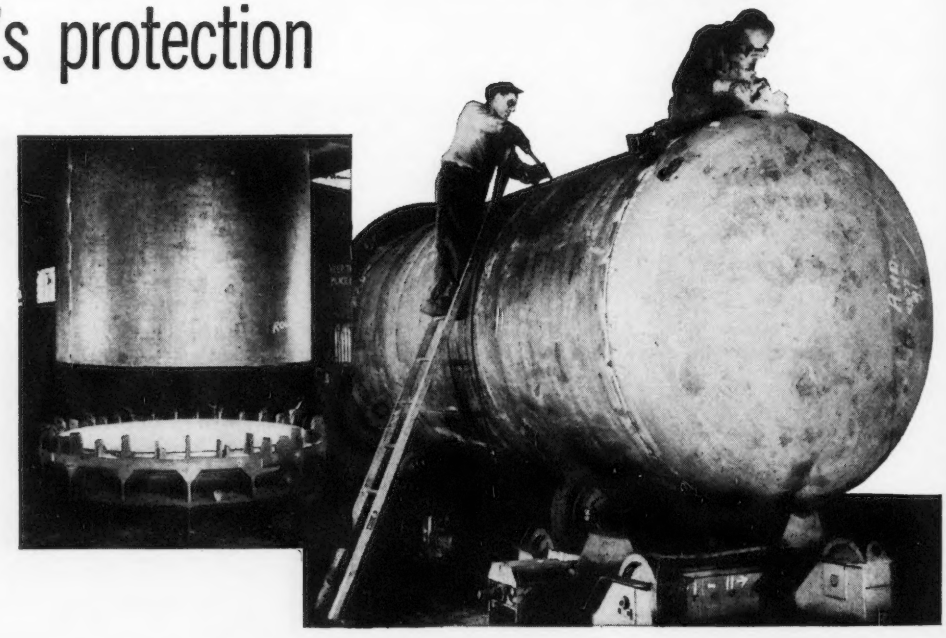

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Titanium in Aircraft Is San Diego Section's January Meeting Topic

K. D. Bennett of Ryan Aeronautical Company spoke on "Titanium—Its use in Aircraft" and R. F. Stratfull of the California Division of Highways, presented a paper on "Concrete Corrosion —Test Procedures and Test Results on San Mateo-Hayward Bridge" at a joint meeting of Western Region and San Diego Section January 25 at the San Diego Hotel.

Mr. Bennett reviewed the history of titanium, then mentioned a few of its outstanding characteristics. He then outlined extraction methods and the troubles encountered in working the metal, purifying the ore, maintaining the metal in a pure state during production procedures. Strength-weight characteristic and strength-heat characteristics were discussed also.

Mr. Stratfull presented an illustrated paper describing the damage done by corrosion on the San Mateo-Hayward Bridge. He described test procedures evolved to study corrosion or locate possible corroding areas of the steel reinforcing rods, examinations made on the bridge and some of the corrective procedures used. He said examinations were made of nearby abandoned concrete structures, with approximately the same composition of material and constructed at approximately the same time as the bridge. This was done by using copper sulfate half cells and voltmeters to determine corroding areas, then the structures were broken open to test the observations.

Fink Discusses Metals for Severe Service at Detroit

F. W. Fink of Battelle Memorial Institute addressed Detroit Section December 8 on Metals for Severe Corrosion Conditions—Tantalum, Titanium, Zirconium and Others. His talk dealt with the metallurgical considerations involving these three metals in terms of their suitability for corrosion conditions somewhat more severe than those ordinarily counted in the chemical industry.

At the January 12 meeting approximately 55 members and guests heard M. D. Moritz of the United States Rubber Company, speak on Plastic Pipes and Fittings—Uses, Design and Corrosion Factors. Types of common plastic pipes were outlined along with their history of use. In addition, design factors involving fundamental physical properties of the various plastics were presented. Aspects of design were stressed in terms of the support and handling of the pipe and other factors. Corrosion considerations were outlined which basically indicated that plastic pipes are serviceable for most aqueous solutions that are not too highly oxidizing in contrast to metallic pipes which are quite suitable for most organic solutions, while being attached by many aqueous solutions under specified conditions.

David M. Collins of the chemical research department of the Chrysler Engineering Division was scheduled to speak at the February 23 meeting of the section.

Uhlig to Speak at Joint Session on March 20

Niagara Frontier Section NACE and Western New York Section's of The Electrochemical Society and the American Chemical Society will hold a joint meeting March 20 at Prospect House, Niagara Falls. Dinner at 6:30 pm will precede the meeting beginning at 8:30 pm.

H. H. Uhlig, head of the corrosion laboratory of Massachusetts Institute of Technology, Cambridge, Mass. will speak on corrosion inhibitors.

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More than 230 authors contributed to the Technical Section in Volume 11, Corrosion.

Gordon Scott Is Speaker At Los Angeles Meeting

Approximately 91 members and guests heard Gordon Scott present a paper entitled "An Outline of a Physical Theory of Underground Corrosion." This first meeting of the Los Angeles Section for 1956 was held at the Rodger Young Auditorium January 18.

Henry Paige

Henry Paige, 31, who joined NACE in October 1948 while a research student at Massachusetts Institute of Technology, died October 5, 1955 as a result of contracting bulbar poliomyelitis.

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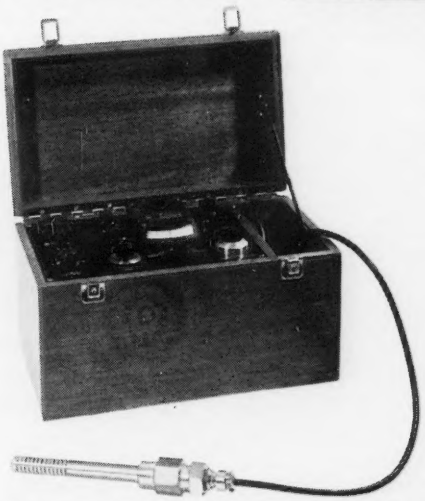

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PERMIAN BASIN SECTION OFFICERS installed January 9 are, left to right, Harold S. Winston, Gulf Oil Corp., first vice-chairman; Harold W. Gray, Jr., Sivalls Tank Co., Odessa; second vice-chairman; John V. Gannon, The Texas Company, Midland, chairman; Roscoe Jarmon, Cardinal Chemical Co., secretary-treasurer.

Permian Basin Section Hears Crawford on Inhibitors

J. D. Crawford of Cardinal Chemical Company spoke on Inhibitor Application in Production Equipment at the January 9 meeting of the Permian Basin Section. Approximately fifty members and guests attended the meeting at which the following officers for 1956 were installed: John V. Gannon, The The Texas Company, chairman; Harold S. Winston, Gulf Oil Corporation, 1st vice-chairman; Jack Gray, Sivalls Tanks Inc., 2nd vice-chairman; Roscoe Jarmon, Cardinal Chemical Company, secretary-treasurer; and John C. Watts, Internal Pipeline Maintenance Company, Trustee.

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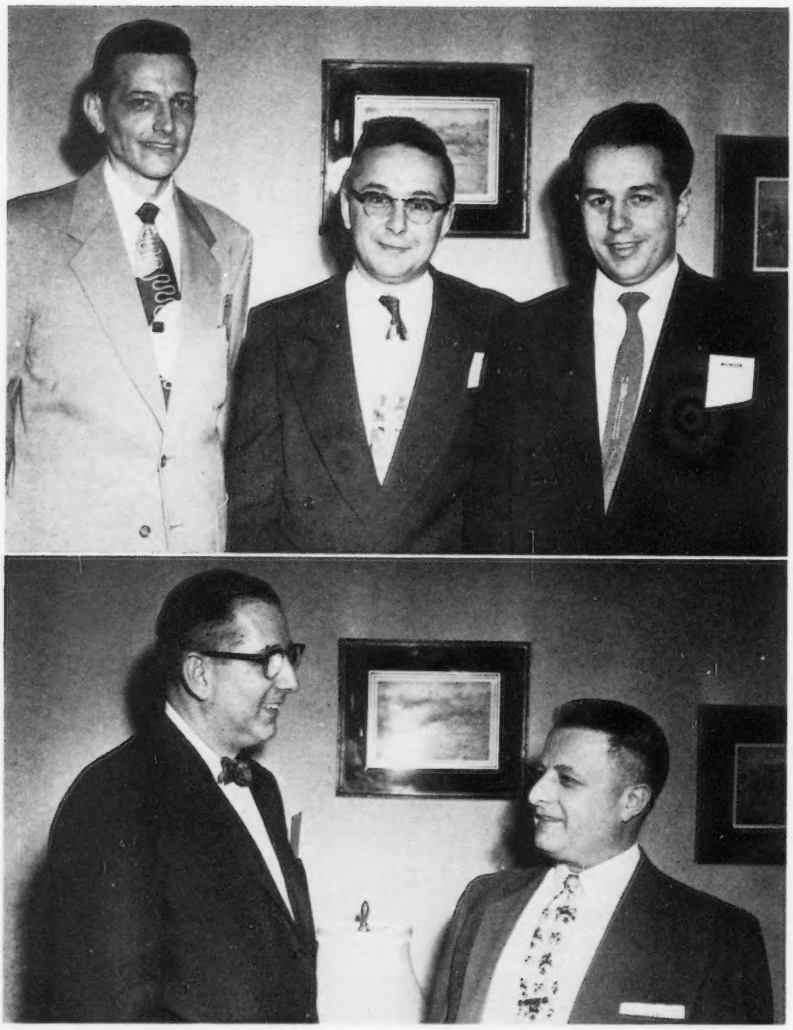

THREE CAME A LONG WAY to attend the Chicago Section's January 17 meeting to hear Dr. C. H. Samans of Standard Oil Co. (Indiana). Top, left to right, Harvey March, Donald Snyder and John Schley, Haynes Stellite Co., Kokomo, Ind. came to Chicago to hear Dr. Samans' lecture on inhibitors. Bottom: Dr. Samans and R. J. Janota, Swift and Co., Chicago, master of ceremonies.

Techniques for Testing Inhibitors Discussed At Chicago Meeting

Several techniques for testing the effectiveness of inhibitors were discussed by C. H. Samans, associate director, Engineering Research, Standard Oil Company (Indiana) at the January 17 meeting of Chicago Section. There were present 88 members and guests including two from Kokomo, Ind. who traveled to Chicago to hear Dr. Samans.

R. B. Janota, Swift and Co. was master of ceremonies. Harco Corp. was host for the fellowship hour with H. W. Hosford as senior host assisted by A. R. Corlett, Bernard Husock, R. H. Weisert and I. C. Lane.

Chicago Section now has 316 regular members, including 28 corporate members, an increase of 32 over last year.

Dr. Samans opened his remarks with a discussion of several laboratory techniques in which visual ratings are used to evaluate the effectiveness of inhibitors in petroleum distillate. The ASTM Turbine Oil Rusting Test, a relatively mild one simulating dynamic conditions well is passed by most commercial inhibitors. The Navy Static Drop Test is much more severe, simulates static conditions and is passed by relatively few inhibitors.

A modification of the navy test adequately simulates intermittent exposure to oil and condensed moisture, but is so severe few inhibitors pass it.

Two newly developed quantitative conductometric tests, one dynamic and the other static were discussed next. They depend on accurate measurement of the decrease in thickness from corrosion of a thin steel strip specimen. Measurement is accomplished readily by electrical conductivity provided the specimen's thickness is the only materially changed dimension.

Results of tests made by all methods were shown. These indicated that nearly all will show up well in dynamic tests, but that few are equally effective under static conditions. Selection of inhibitors is determined on the basis of cost for the protection achieved.

Application of the conductometric technique to a corrosion probe suitable for use in active process units was described. A typical probe and the curve it provides illustrated the manner in which corrosion varies with operating conditions.

Dr. Samans, author of a textbook on metallurgy "Engineering Metals and Their Alloys," has published several technical papers.

Lehigh Valley Section Hears Frank L. Whitney, Jr. Discuss Metal Selection

Frank L. Whitney Jr., Monsanto Chemical Company, St. Louis and president of the National Association of Corrosion Engineers, spoke January 16 at a meeting of Lehigh Valley Section on Selection and Evaluation of Metals and Alloys for Equipment in Corrosive Atmosphere. Thirty-five members, better than 75 per cent of the local membership and two guests were present to hear Mr. Whitney's presentation.

In addition to the technical discussion Mr. Whitney expressed his views on the need for consolidated efforts in research and education to better equip and train corrosion engineers. He said a program is also necessary whereby data may be compiled from different industries and their research projects to assist in the prediction of a material's suitability to a particular environment.

Following Mr. Whitney's presentation a nominating committee presented a slate of officers for the section for 1956-57.

Technical Committees Are Invited to Philadelphia

Technical committees that wish to do so are invited to meet October 15, the day before opening of Northeast Region's Fall 1956 meeting at Philadelphia. October 15 has been reserved at the Drake Hotel for the meetings of committees.

Shreveport Hears Graves

J. H. Graves, Tidal Pipeline Co., Joinerville, Texas was the scheduled speaker at Shreveport Section's January 17 dinner meeting. His topic was Cathodic Protection of Internal Tank Bottoms.

Central Oklahoma Section Hears Y. W. Titterington

Yale W. Titterington of Corrosion Services Inc., Tulsa, spoke on "Galvomag—High Potential Anodes Compared to High Purity Magnesium Anodes." Fifteen members attended the January 24 meeting at the Tropical Cafe in Oklahoma City. It was announced that the next meeting was scheduled for February 28.

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More than 500 periodicals are canvassed for abstracts appearing in Corrosion Abstracts.

Metal Corrosion in Ancient, Medieval Times Is Topic At New England Session

Preservation of metals in ancient and medieval times was a serious problem for which engineers often had no adequate answers. This some times necessitated use of precious metals as weights. Frederick G. Kilgour, Yale University Medical Library was principal speaker on the topic "Corrosion of Metals in Ancient and Medieval Times" February 1 to members and guests of Southern New England Section. He discussed gold, silver, lead, tin and bronze as used in ancient times and in medieval structures.

Cases containing metallic artifacts from olden times frequently contain desiccants, but these often fail to prevent further corrosion of displayed items, Mr. Kilgour said.

Section officers for 1956 were installed as follows: Charles B. Chapman, Hartford Electric Light Co., Hartford, Conn., chairman; David H. Thompson, American Brass Co., Waterbury, vice-chairman; E. A. Tice, The International Nickel Co., Inc., Hartford, secretary-treasurer.

Houston Compressor Station Talk Delayed to March 27

The March meeting of the Houston Section has been moved to March 27 because of a conflict of dates with the 12th Annual Conference and 1956 Corrosion Show. Normally, the section meets the second Tuesday of each month.

"Design and Installation of a Cathodic Protection System in a Compressor Station Plant Yard," by R. G. Ranson, Tennessee Gas Transmission Co., Houston is the technical paper scheduled for the meeting.

"Coatings and Cathodic Protection," by C. G. Munger, Amercoat Corp., Southgate Cal. was the technical paper scheduled for the February meeting. Subjects dealt with in Mr. Munger's paper were protection against corrosion of metals buried in soil or immersed in fresh or salt water. Cathodic protection combined with proper coating has been successful in providing adequate protection, he stated.

Mr. Munger is vice president in charge of manufacturing and research for his firm. He is a national director of NACE, is co-chairman of the technical practices committee on coatings for chemical corrosion, and is an NACE corporate member representative.

Puckett Is San Francisco Bay Section Chairman

G. J. Puckett, Dow Chemical Co., Pittsburgh, Cal. has been elected chairman of San Francisco Bay Area Section. Mr. Puckett and the following officers took charge January 1: James K. Ballou, Standard Oil Co. of Cal., vice-chairman and Henry R. Strickland, Haynes Stellite Co., secretary-treasurer, both of San Francisco.

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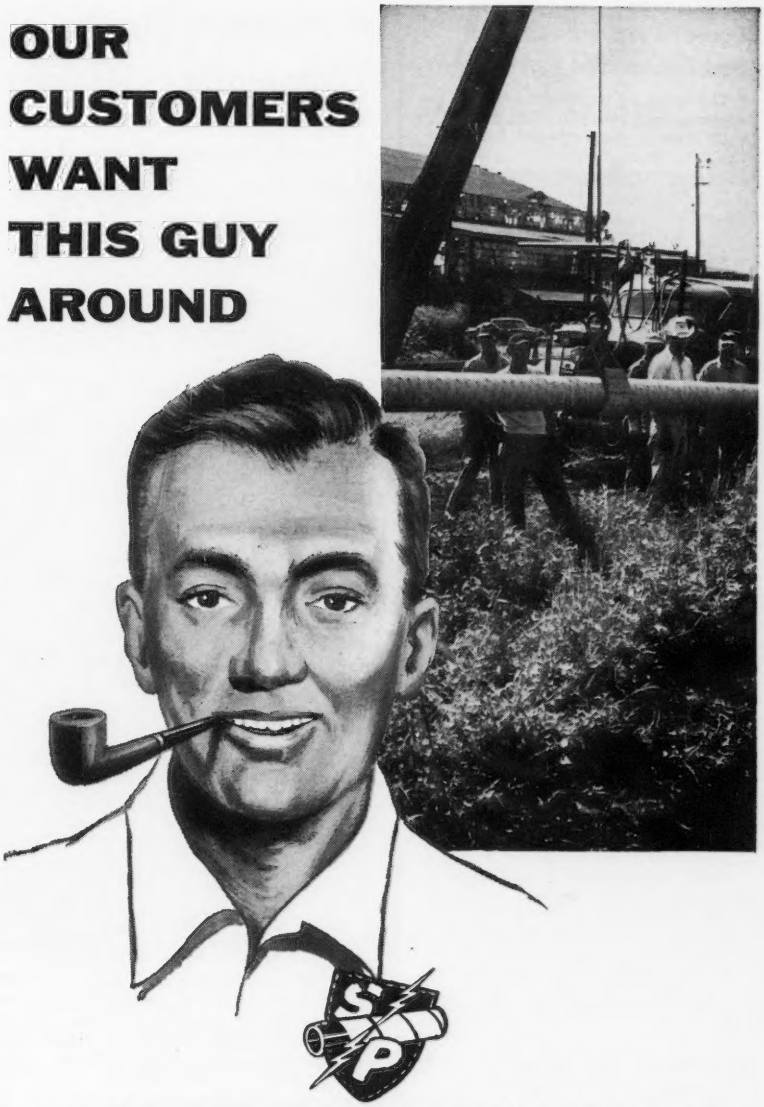
By far the greater part of all technical material published in Corrosion is found in no other periodical. Two of every three editorial pages contain material with reference value.



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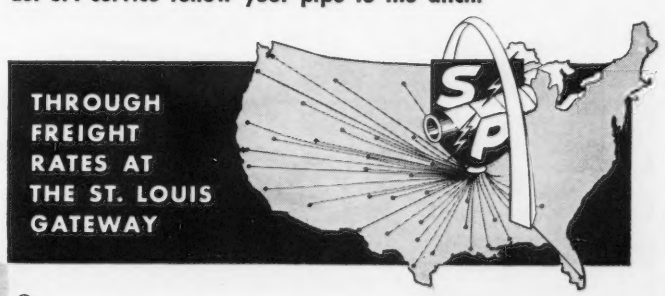

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Papers Approved for Publication in Corrosion

The following manuscripts have been approved and are scheduled for early publication in the Technical Section of CORROSION:

A Practical Corrosion Service Program, B. J. Philibert.

Selection of Materials for Some Petroleum Refinery Applications, J. F. Mason, Jr.

Effect of Cold Work and Heat Treatment on the Rate of Dissolution of Purest Aluminum in Acids and Bases, M. E. Straumanis and Y. N. Wang.

Corrosion Engineering Problems in High Purity Water, D. J. DePaul.

Use of Organic Corrosion Inhibitor, Charles Fiske and Paul Mernitz.

Sealing of Titanium and Titanium-Base Alloys in Air, Hal W. Maynor and Roy E. Swift.

Integration of Corrosion Control in Pier Substructures, Carl R. Johnson.

Application of Cathodic Protection to the Inside of a Tank, J. H. Graves.

Economic Survey of Underground Corrosion Preventive Measures, Dean C. Glass.

Inhibiting Corrosion of Steel, Aluminum and Magnesium Intermittently Exposed to Brines, George E. Best and John W. McGrew.

Corrosion Testing of Aluminum. Part 1—High Velocity Test Method in Aqueous Solutions. Part 2—Development of a Corrosion Inhibitor, S. B. Twiss and J. D. Guttenplan.

Recent Navy Experience with Saran and Vinyl Coatings, W. W. Cranmer.

Intrinsic Protection of Water Mains, M. Unz.

Corrosion in Processing Acetic Acid and Related Compounds, E. V. Kunkel.

A Simple Graphical Method for Checking Adequacy of Stress Corrosion Specimen Dimensions Against Stress Concentration, Robert H. Hay.

Corrosion Investigations Related to Adsorption Studies, C. C. Nathan.

Petroleum, Pipe Line, Utilities and High Temperature Sessions Set at San Antonio

Committeemen Named for South Central Region's October 23-26 Meeting

Alamo Section has completed preliminary planning for the 1956 South Central Region meeting in San Antonio, Texas. It is scheduled for October 23-26 at the Gunter Hotel. Joseph W. Gibson, D. W. Haering & Co., Inc., San Antonio, General Arrangements Committee chairman named members of his committee as follows:

W. W. Elley, Southwestern Bell Telephone Co., San Antonio, local arrangements.

Norman Hackerman, University of Texas, Austin, technical program.

John D. Sudbury, Continental Oil Company, Ponca City, Okla., technical program.

Max F. Schlather, United Gas Pipe Line Company, San Antonio, finance.

Herschel C. McDonald, United Gas Pipe Line Company, San Antonio, finance.

David N. Henry, United Gas Pipe Line Co., San Antonio, entertainment.

Mdms., W. W. Elley and Max F. Schlather, ladies' program.

Paul V. Sanders, D. W. Haering & Co., Inc., San Antonio, publicity and printing.

Philip S. Donnell, City Water Board, San Antonio, publicity and printing, San Antonio.

Carl M. Thorn, Southwestern Bell Telephone Co., San Antonio, registration.

Zane V. Morgan, Texas Acidizers, Inc., Seguin, Texas, properties and communications.

C. R. Goodrich, Consultant, San Antonio, field trips and transportation.

Six symposia have been scheduled for the 1956 South Central Region meeting to be held October 23-26 at San Antonio. Presentation of technical papers will be concentrated in two days, October 25 and 26. Norman Hackerman, University of Texas, Austin and John D. Sudbury, Continental Oil Co., Ponca City, Okla. are co-chairmen of the technical program.

Symposia scheduled are:

Thursday, October 25

Morning:

Corrosion in the Utilities Industries. Glyn W. Beesley, Dallas Power & Light Co., Dallas; P. Ray Harrell, Southwestern Bell Telephone Co., Dallas, co-chairmen.

Elevated and High Temperature Corrosion. "To be announced."

Afternoon:

Corrosion in the Transportation Industries. J. R. Spraul, General American Transportation Corp., Houston.

Cathodic Protection. Marshall E. Parker, Jr., Cormit Engineering Co., Houston, chairman.

Friday, October 26

Morning:

Pipe Line Corrosion. Loyd B. Nelson, Shell Pipe Line Corp., Houston; A. L. Stegner, Tennessee Gas Transmission Co., Houston, co-chairmen.

Corrosion in Oil and Gas Well Equipment. W. F. Oxford, Jr., Sun Oil Co., Beaumont, Texas; Jack L. Battle, Humble Oil & Ref. Co., Houston, co-chairmen.

Papers for presentation during the symposia are being scheduled by their respective chairmen. Persons who have suitable papers are invited to communicate with the appropriate chairman.

Alamo Section, in charge of arrangements for the meeting is planning a full schedule of events in addition to the technical symposia.

San Antonio Activities Are Scheduled Through October

Activities have been scheduled through October by San Antonio Section. These include six section meetings and the 1956 South Central Region meeting which will be held in San Antonio October 23-26.

Joseph W. Gibson will be featured speaker at the March 20 meeting on the subject "Intermediate Principles of Chemistry as Applied to Corrosion." His talk is one in a series on corrosion principles which began with the February 21 session on elementary principles with W. W. Elley as speaker.

Norman Hackerman, University of Texas is scheduled to talk on Advanced Principles of Chemistry as Applied to Corrosion at the April 17 meeting.

Zane V. Morgan was the scheduled speaker at the January 17 meeting of the section on "Chemical Service to the Petroleum Industry."

Other activities scheduled include: May 15, the film "Cavitation" by American Brass Co.; September, smoker and business meeting on 1956 South Central Region convention. No meetings are scheduled during June, July and August.

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BACK ISSUES OF VOLUME 11

Copies of back issues of Volume 11, January-December, 1955 are available except July. Persons who customarily bind all or parts of Corrosion and who lack issues to make the volume complete may get back copies at the following prices per copy, postpaid, remittance in advance: NACE members, 50 cents; Non-members, $1. An additional charge of 65 cents per package is made for mailings to addresses outside the United States, Canada and Mexico.

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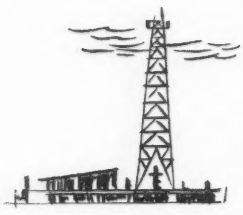

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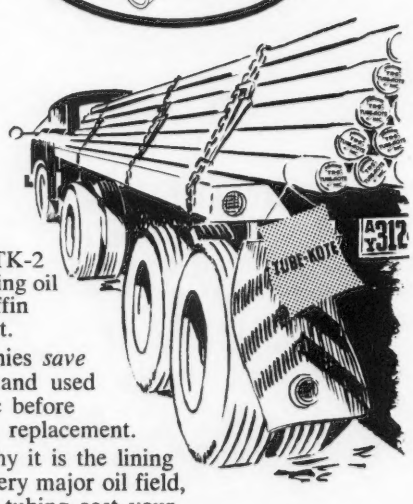

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LaJolla Marine Corrosion Sessions Set April 18-20

Measures for protection against biological, physical and chemical deterioration of wood, metal and concrete structures in a marine environment will be discussed at LaJolla, Cal., April 18-20. The Conference on Marine Corrosion and Fouling Problems, sponsored by the University of California, LaJolla and the National Association of Corrosion Engineers, will cover four major topics: Introduction to the study of deterioration, fundamental causes of deterioration, deterioration investigation and deterioration mitigation procedures.

Registration is $25. Persons interested in attending may send remittance payable to Regents of the University of California, Conference Registration, University Extension, University of California, Los Angeles 24, Cal. Attendance is limited to 100 persons.

Tulsa Short Course Lecturers Are Named

The Seventh Annual Corrosion Short Course for Pipeliners was held February 15-17 at Hotel Mayo, Tulsa. Tulsa Section was sponsor of the course.

The program included:

Wednesday, February 15

Introduction, James C. Bell, Service Pipe Line Co., Tulsa.

Corrosion in Action, Inco film.

Fundamentals of Pipe Line Corrosion and Its Control by Jack P. Barrett, Stanolind Oil and Gas Co.

Measurements and Instruments for Detecting and Controlling Corrosion, James R. Cowles, consulting engineer.

Corrosion and Corrosion Control Surveys, Marshall E. Parker, Cormit Engineering Co., Houston.

Thursday, February 16

Use of Coatings in Corrosion, F. M. Hieronymous, Barrett Division, Allied Chemical and Dye Corp.

Cathodic Protection with Galvanic Anodes, W. P. McCollister, Mississippi River Fuel Corp.

Cathodic Protection with Impressed Currents, Dean O. Griffith, Shell Pipe Line Corp.

Friday, February 17

Miscellaneous Corrosion Control Equipment and Devices, William L. Mabrey, Colorado Interstate Gas Co., Lakin, Kans.

Procuring Power for Rectifier Units, J. L. Callahan, Gulf Refining Co.

Coordinating Pipelining and Corrosion Control, O. W. Everett, Oklahoma Natural Gas Co.

Management Views on Corrosion Control, J. E. Green.

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NACE MEETINGS CALENDAR

Mar.

5 North Texas Section. In Fort Worth. Submerged Combustion, Walter Hart, Gulf Oil Corp.

20 Chicago Section. Engineer's Club, 315 South Federal St., Chicago. Survey of Pipeline Coating Practices and Protection Costs, D. C. Glass, Pure Transportation Co.

20 Genesee Valley Section. German Club.

27 Southwestern Ohio Section. Shuller's Restaurant. Reading, Ohio, 6:30 pm. Methods of Corrosion Control, Frederick Fink, Battelle Memorial Institute, Columbus.

27 Houston Section. John's Restaurant. Protection of Underground Plant at Pump Stations.

29 Kanawha Valley Section. Charleston, W. Va. Corrosion Inhibitors, Theory and Practice, Harry C. Gatos, Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Mass.

29 Sabine-Neches Section. Orange, Texas. Panel discussion on Plant Painting Problems, Vernon Brown, Columbia-Southern Chemical Corp., Lake Charles, La., moderator.

Apr.

2 North Texas Section. Dallas, annual picnic.

5 Pittsburgh Section. Mellon Institute, Oakland, Pa.

10 Houston Section. John's Restaurant. Cathodic Protection of External Ship Hulls, H. S. Preiser, Bureau of Ships, U. S. Navy.

17 Chicago Section, Chicago Engineers' Club, 315 S. Federal St., Chicago. Economic Control of Corrosion Under Mildly Corrosive Conditions, E. F. Moorman, International Harvester Company.

17 Cleveland Section. Hotel Manger. Corrosion in the Petroleum Industry, L. Mills.

17 Genesee Valley Section. German Club. Annual business meeting, motion picture.

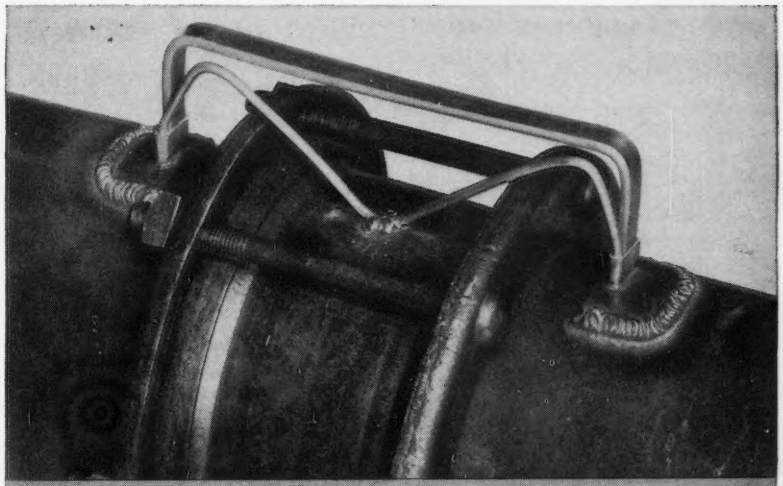
24 Southwestern Ohio Section. Shuller's Restaurant. Reading, Ohio. Panel Discussion: Protective Coatings; Atmospheric, Cliff Weymiller, Proctor & Gamble Co.; Underground, George Pemberton, Cincinnati Gas and Electric Co.; ceramic, William Barrows, Barrows Porcelain Enamel.

26 Sabine-Neches Section, Orange, Tex. Corrosion Problems in Gas Industry, Joe Waterfield, United Gas Corp.

No date. Schenectady Section. Joint dinner meeting with American Society of Electroplaters.

Ohio University Annual Conference Set on May 4

The Annual Conference for Engineers of the College of Engineering, Ohio State University will be held May 4 on the Campus at Columbus. Inquiries and reservations should be addressed to Harold A. Bolz, Associate Dean; College of Engineering, The Ohio State University, Columbus 10, Ohio.



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Full Program Ready for Ladies Attending NACE Conference in New York

A full program for ladies visiting New York during the NACE 12th Annual Conference has been arranged. Ladies headquarters at Hotel Statler will be the Washington Room on the mezzanine floor.

The program is as follows:

Sunday, March 11

3:30-5:30 pm—Pre-conference tea. Washington Room.

Monday, March 12

12:30-2 pm—Buffet luncheon, Washington Room. Welcome lunch of Ladies' Committee. No ticket required.

Tuesday, March 13

8:30-9:30 am—Coffee hour, Washington Room. No ticket required.

2:30 pm—Special program at Lever House, followed by tea as guests of Lever Brothers. No ticket required.

6 pm—Fellowship hour, Penntop Room, Hotel Statler.

Wednesday, March 14

12:30-2 pm—Luncheon and fashion show, Cotillion Room, Hotel Pierre. Tickets required.

Annual Banquet, Dinner, entertainment.

Thursday, March 15

8:30-9 am—Coffee hour, Washington Room.

10 am—Visit to United Nations building. Tickets required.

Tickets for National Broadcasting Corporation and Columbia Broadcasting System television programs for Monday through Thursday can be obtained at ladies' headquarters.

FPVPC Council to Meet

The spring meeting of the Federation Council of the Federation of Paint and Varnish Production Clubs will be held Saturday, March 24 at the Statler Hotel Los Angeles.

Personnel of Local Arrangements Groups For NACE New York Conference Are Named

NACE CONFERENCE TECHNICAL PROGRAM

MONDAY—March 12
- Committee meetings all day.

TUESDAY—March 13
- Business Meeting
- Corrosion Principles Symposium
- Chemical Inhibitor Symposium
- Refinery Industry Symposium (Part 1)
- Oil and Gas Production Symposium
- High Purity Water Symposium
- Educational Lecture

WEDNESDAY—March 14
- Chemical Industry Symposium (Part 1)
- General Pipe Line Symposium
- Steel Metallurgy and Corrosion
- Chemical Industry Symposium (Part 2)
- Power and Communications Symposium
- Pipe Line Group Discussions
- Educational Lecture

THURSDAY—March 15
- Cathodic Protection Symposium
- Plastics Symposium
- Refinery Industry Symposium (Part 2)
- Elevated Temperature Symposium
- Protective Coatings Symposium
- Worldwide Developments in Corrosion
- Educational Lecture

FRIDAY—March 16
- General Corrosion Round Table
- Pipe Line Underground Round Table

A summary of the Technical Program for the 12th Annual NACE Conference was published in February, 1956 CORROSION beginning on Page 75. A table of technical committee meetings appeared in the same issue on Page 62.

Persons on committees making arrangements for the NACE 12th Annual Conference and 1956 Corrosion Show are as follows:

Exhibits Committee—Clark A. Bailey, Johns-Manville Sales Corp., New York, chairman; Charles G. Gribble, Jr., Metal Goods Corp., Houston; Howard E. Johnston, Dearborn Chemical Co., Linden, N. J.; T. D. Williamson, Jr., T. D. Williamson, Inc., Tulsa.

Registration and Information Committee—A. F. Minor, American Tel. & Tel. Co., New York, chairman; T. J. Maitland, American Tel. & Tel. Co., vice-chairman; Seymour J. Fiebach, Carboline Co., New York; W. J. Flynn, Minnesota Mining & Manufacturing Co., Ridgefield, N. J.; E. W. Hilbert, New York Telephone Co., New York; C. E. Kreutzberg, New York Telephone Co., Bronx; John J. Oates, Subox, Inc., Hackensack, N. J.; S. N. Palica, Consolidated Edison Co. of N. Y., Mt. Vernon, N. J.; W. F. Reeder, New Jersey Bell Telephone Co., Newark, N. J.; H. J. Schmidt, Jr., Chemical Fire & Rustproofing Co., New York; H. F. Trusler, Jr., Pittsburgh Coke & Chemical Co., New York; W. S. Woodward, New York Telephone Co., Bronx.

Entertainment and Hospitality Committee—J. I. Montel, Hammond-Montel, Inc., Maspeth, L. I., chairman; G. D. Lain, American Iron and Steel Institute, New York, vice-chairman; George Deuber, Deuber Laboratories, New York; J. G. Fitzpatrick, Hills-McCanna Co., Jackson Heights, N. Y.; F. B. Koeffler, Barrett Div., New York; D. E. Long, Del Products, New York; E. F. Miller, Hills-McCanna Co., Jackson Heights, N. Y.

Publicity Committee—Malcolm W. Riley, Materials and Methods magazine, N. Y., chairman; Carl R. Johnson, Port of New York Authority, vice-chairman; James Battle, National Lead Co. Laboratories, Brooklyn; E. Rowland English, Flotation Co., Inc., Elizabeth, N. J.; John C. Klinger, Oildom Publishing Co., Bayonne, N. J.; George Kurr, Federated Metals Div., American Smelting & Ref. Co., New York; E. T. Pearson, Public Service Electric & Gas Co., Maplewood, N. Y.

Ladies' Committee—Mrs. F. L. Whitney, Jr., honorary chairman; Mrs. Beatrice Bailey, Consolidated Edison Co. of New York, Inc., chairman; Mrs. Kempton H. Roll, co-chairman; Mrs. Clark A. Bailey, Miss Marguerite Bebbington, Mrs. Morton Bermann, Mrs. E. G. Brink, Mrs. A. B. Campbell, Mrs. R. A. Davis, Mrs. L. B. Donovan, Mrs. William F. Fair, Jr., Mrs. T. F. P. Kelly, Mrs. Robert E. Kerr, Mrs. Frank E. Kulman, Mrs. R. J. Law, Mrs. F. J. LeFebvre, Mrs. E. F. Miller, Mrs. A. F. Minor, Mrs. J. I. Montel, Mrs. Malcolm W. Riley, Miss Rosemary B. Smith, Mrs. H. O. Teeple.

Lubrication Engineers Meet

The American Society of Lubrication Engineers will have a panel session, 45 technical papers and a lubrication engineering course at its 11th Annual Meeting and Exhibit April 4-6. The meeting will be at the William Penn Hotel, Pittsburgh.

Putting Price Before Quality and Experience Is Like Putting the Cart Before the Horse

Put the cart before the horse and you know how far you will get.

Put bargain price before quality and experience in coating and wrapping pipe and the same thing happens. Unfortunately, it doesn't happen as quickly. It's *after* laying the line when corrosion cuts through and multiplies your original cost through damage, removal and re-laying the pipe. The best way to avoid this is to pay for quality coated and wrapped pipe to start with. At MAYES BROS. INC. you will find that quality and experience are the watchwords that put lasting PERMANENCE—TROUBLE-FREE PERMANENCE in the pipe you lay.

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NATIONAL ASSOCIATION
OF CORROSION ENGINEERS
Statler Hotel, New York, N. Y.
March 12-16, 1956

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N. Y. Technical Program Is Virtually Unchanged

The technical program to be given at New York March 12-16 is virtually unchanged from that listed in the February issue of CORROSION. The 14 symposia, three discussion sessions and three educational lectures will be held except as indicated by changes listed below:

In the Refinery Industry symposium the paper "High Temperature Hydrogen Sulfide Corrosion in the Presence of Hydrogen" by C. H. Samans, Standard Oil Co. (Indiana) has been withdrawn.

In the Oil and Gas Production Symposium a paper, "Analysis of Corrosion Pitting by Extreme Value Statistics—Application to Oil Well Tubing Caliper Surveys," by G. Eldredge, Shell Development Co., Emeryville, Cal., has been added.

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By far the greater part of all technical material published in Corrosion is found in no other periodical. Two of every three editorial pages contain material with reference value.

Registration Hours For Conference Set

Hours for registration for the 12th Annual Conference and 1956 Corrosion Show at Hotel Statler, New York, March 12-16 have been set. The desk, located on the mezzanine floor, will open at noon Sunday, March 11 and remain open until 5 pm. On succeeding days, Monday and Tuesday, March 12-13, the desk will be open from 8 am to 5 pm; on Wednesday and Thursday, March 14 and 15 it will be open from 9 am to 5 pm and on Friday, March 16 from 9 to 10 am.

The advance registration desk will be on the mezzanine floor. Persons who have sent in advance registration cards will be able to pick up a packet containing their material with minimum delay.

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Corrosion is indexed annually by Engineering Index.

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More than 230 authors contributed to the Technical Section in Volume 11, Corrosion.

NACE Corrosion Show At Statler Hotel Sold Out

All 120 booths at the Corrosion Show to be held concurrently with the 12th Annual NACE Conference at Hotel Statler New York have been sold. The show promises to be at the same time the largest and most diversified ever held by NACE.

Arrangements have been completed to have a booth for National Association of Corrosion Engineers Central Office staffed with personnel from Houston. Members and prospective members are invited to visit the booth to inspect samples of NACE publications and to ask questions about NACE and its activities.

Exhibitors assigned space since the report in February CORROSION are:

The Carborundum Co., M. J. Crose Mfg. Co., Ebasco Services, Inc., General American Transportation Corp., Kanigen Div.; Knapp Mills, Inc.; M. C. Miller, Pipe Line Anode Corp., Arthur Tickle Engineering Works, Inc., Valvco, Inc.

Asphalt Accelerated Test

A method of testing the weathering resistance of asphalt has been developed by the National Bureau of Standards. The test involves exposing samples of the asphalt inside a rotating metal drum and alternately exposing the material to light, water spray and cold. Ratings of durability are determined by a spark test which provides a photographic record of holidays.

NOTICE ON PAYMENT OF 1956 NACE DUES

Invoices for 1956 membership dues have been sent to all Active and Junior NACE members. These dues are payable January 1, 1956. The NACE by-laws state that no member with dues in arrears for three months shall receive the publications of the association until such dues are paid.

• Accordingly the names of Active and Junior members whose 1956 dues have not been received by March 30, 1956 will be removed from the mailing list to receive CORROSION. No mailings of CORROSION will be made to delinquent members until dues are paid.

Steelcote Announces

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IN CANADA: Steelcote Mfg. Co. of Canada, Ltd., Rodney, Ontario

NO NEED TO REMOVE RUST TO PAINT!

In magnified illustration, note how film of ordinary rust inhibiting paint at center stays on surface; does not penetrate pores to contact sound metal.

Segment at right illustration shows how Steelcote Halts-Rust penetrates pores, contacts and protects sound metal surfaces underneath.

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NATIONAL CARBON COMPANY *Introduces*

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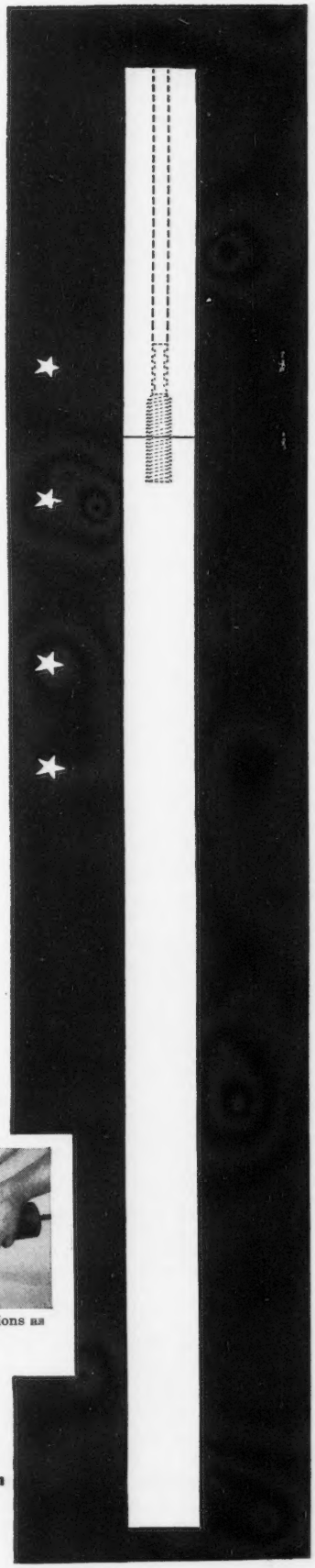
NEW NATIONAL TRADE-MARK

3" x 60" NA GRAPHITE ANODE
With Type QA Connection



★ *Dependable:* Proved assembly technique assures top quality cable-to-anode connection for either factory or field assembly.

★ *Long-Lasting:* Entire anode of NA graphite assures maximum life in all environments. Electrical connection between cable and anode in interior of anode prevents premature failure due to localized wear at anode end.

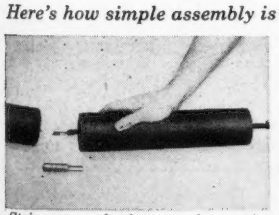
★ *Flexible:* Standard stock components assemble in minutes with cable to your size, type and length-specifications.

★ *Strong:* Strength of cable-to-anode connection far surpasses requirements — exceeds breaking strength of size 4, 6 or 8 cable.

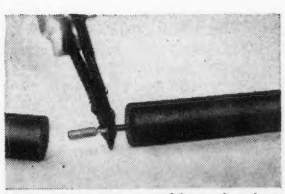
Here's graphite cathodic protection anode construction that will meet your most rigorous requirements. The convenience, dependability and long life of "National" 3" x 60" NA Graphite Anode with Type QA Connection make them your best bet for all impressed current applications. Be sure—specify them on your cathodic protection jobs.

Patents Pending

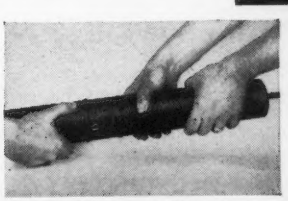
Here's how simple assembly is:



Strip one end of connecting cable and insert thru 15" top anode section.



Join connector to cable end using crimp or solder-type connector.



Cement and join anode sections as illustrated in above photo.

SEE THEM AT BOOTH 111. 1956 N. A. C. E. Corrosion Show
March 12-16, 1956, Hotel Statler, New York City

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Procedure Is Given for Selection of Persons To Receive Whitney and Speller Awards

Procedure in the Selection of Persons to Receive The Willis Rodney Whitney and Frank Newman Speller Awards As Approved by the Board of Directors December 4, 1953, and Revised March 6, 1955.

The board of directors of the National Association of Corrosion Engineers in a regular meeting on January 17, 1947 authorized the presentation annually of two awards by the association.

The Willis Rodney Whitney Award is given in recognition of public contributions to the science of corrosion. A contribution to science is defined as the development of new information or the development of a more satisfactory theory which contributes to a more fundamental understanding of corrosion phenomena.

The Frank Newman Speller Award is given in recognition of public contributions to corrosion engineering. A contribution to engineering is defined as the development or improvement of a method, apparatus or material by which the control of corrosion is facilitated or made less costly.

Committee Appointment

Not later than May 15th of each year and preferably in advance of the annual conference, the president (or president-elect) for the year in which the award is to be made, in consultation with the immediate past president for this same year, shall appoint an awards committee. This committee shall consist of at least six members with the immediate past president of the association (as referred to above) serving as chairman. In the event the immediate past president should be unable to serve, the president (for the year the award is to be made) shall appoint a chairman. The other members of the committee should be outstanding members of the association. At least two but not more than four members of the awards committee should be re-appointed from the awards committee of the preceding year. No member shall serve on the awards committee for more than two years in succession. Any member who is lost by the committee through resignation or for any other reason, shall be replaced by appointment by the president of the association.

The chairman of the awards committee shall arrange to keep reasonably detailed records of the activities and discussions of the committee. These records shall be made available to succeeding awards committees.

Candidates to Be Considered

The list of candidates to be considered for the awards shall include:

NOTES FOR GUIDANCE OF AWARDS COMMITTEE

A. The committee shall not recommend the same individual for both awards in any one year.

B. Previous recipient of an award is not eligible to receive the same award again.

C. The recipient of one award is not barred from receiving the other award for some other year.

D. In considering the qualifications of those nominated for awards, the nominee's total contributions should be taken into account and recent activities should not take precedence over the recognized results of earlier work. Other things being equal, awards should be made to the candidates who have been contributing consistently for the longest period.

E. Candidates need not be residents of North America.

F. Candidates need not be members of the National Association of Corrosion Engineers.

G. Awards shall be limited to living persons.

H. Recipients of the Willis Rodney Whitney and the Frank Newman Speller Awards and the recipient or recipients of the Junior Award should be guests at the annual NACE banquet.

I. The president and vice president of the association and the chairman of the awards committee should not be considered as candidates for awards.

A. The names of those proposed but who did not receive awards in the two immediately preceding years.

B. The names of all those proposed in previous years who in the judgment of the committee members should be retained on the list regardless of the year proposed.

C. The names of those proposed by the chairmen of the regional divisions in accordance with the wishes of the members of the division. Nominations may be made by local sections or may be proposed directly to the chairman of a region by individual members. In any case, nominations should be accompanied by an appropriate statement of the basis of the proposal. This statement shall be reproduced and submitted to all members of the awards committee. The committee should have such statement for all nominees to be considered.

Prior to June 1st of each year the regional chairmen shall forward to the chairman of the awards committee all names proposed for awards, accompanied in each case by summaries of the reasons presented in support of each proposal but with no indication of the number of duplicate nominations of any individual. The object of this latter provision is to insure that awards will be made on a basis of accomplishments and other qualifications rather than by any semblance of a popular vote.

Not later than April 1st (or the publication date of April issue of CORROSION) of each year the executive secretary shall notify the membership, either by direct letter or through publication in CORROSION of their privileges in this regard as set forth here.

D. Any names proposed by the members of the committee prior to June 1st of each year.

At the discretion of the committee members the resultant list of candidates may be reduced to a workable number by elimination of those known to lack the necessary qualifications.

Contributions Are Listed

As a basis for further consideration by the committee, the headquarters staff of the association shall provide the committee, through its chairman, with a record of the contributions of each final candidate in the form of a list of his published papers and other works. Such records available in the headquarters office may be supplemented by additional information on the candidates' qualifications which may be secured by any member of the committee from other sources, such as friends of the candidates and especially from the proposers of the candidates who should be asked to provide their reasons for suggesting them and a summary of their accomplishments. Ordinarily, the candidates should not be made aware that they are being considered for awards by seeking such information from them directly.

The required activity of the headquarters staff should be facilitated by appropriate use of the literature abstract filing system.

If the committee should decide that none of those nominated are worthy of the awards, or if no nominations are received, the committee may recommend to the directors that one or both awards be withheld for reasons to be stated in their report to the directors.

Recommendations of the committee shall be reported by the chairman of the committee to the board of directors through the executive secretary not later than December 1st.

In the event that the committee should be unable to reach a decision on can-

Nominations for the Whitney and Speller Awards

The Willis Rodney Whitney Award is given in recognition of public contributions to the science of corrosion. A contribution to science is defined as the development of new information or the development of a more satisfactory theory which contributes to a more fundamental understanding of corrosion phenomena.

The Frank Newman Speller Award is given in recognition of public contributions to corrosion engineering. A contribution to engineering is defined as the development or improvement of a method, apparatus or material by which the control of corrosion is facilitated or made less costly.

Nominations may be made by local sections or may be proposed directly to the Chairman of a Region by individual members up to June 1, 1956. In any case, nominations should be accompanied by an appropriate statement of the basis of the proposal.

didates for either or both awards, the committee shall provide the board with a list of all those proposed for consideration and the number of votes received by each on the last ballot of the members of the committee.

The board of directors shall then determine, either in a regular meeting, or by letter ballot, returnable not later than December 15th in each year, whether the recommendations of the awards committee are to be accepted and the awards made as proposed. If the board of directors does not approve the granting of an award, or awards, as proposed by the awards committee, then such award, or awards, will not be made for the year in question. In the event that the awards committee has been unable to reach a decision on candidates for one or both awards, the board of directors shall determine by majority vote whether an award (or awards) shall be made and to whom it (or they) shall be granted.

Presentation of Awards

After the board of directors has chosen the recipients of the awards, the president of the association shall notify the recipients not later than January 15th, and shall invite each of them to be present at the annual meeting or other occasion when the awards are to be presented. The chairman of the committee shall arrange to have appropriate certificates inscribed for presentation to the recipients of the awards and on occasion of any public presentation of the awards he shall present the recipients to the president or whoever may be serving in his stead as chairman of the meeting, to receive the awards at his hands.

The actions of the awards committee shall be confidential and confined to consideration only as outlined in the procedure until such time as the president receives acceptance or rejection from the awardees following his notification to them. After receiving acceptance of an award or awardee, the president shall so notify the executive secretary who may publicize the information prior to the actual presentation of the award or awards.

Water Use by 1975 Forecast At 453 Billion Gallons

Daily average consumption of water in the United States is expected to rise to 453 billion gallons daily by the U. S. Department of Commerce. This prediction is based on data collected by the Water and Sewage Industry and Utilities Division, Business and Defense Services Administration.

Industrial and miscellaneous use, including manufacturing industries, mineral industries, commercial, air conditioning, military, resorts, motels and the like are estimated to increase their total intake from the present 60 billion to 115 billion gallons daily by 1975. Water used for steam generation of electric power will rise from nearly 60 to 131 billion gallons daily in the same period.

Copies of the Business Service Bulletin, BSB-136 "Water Use in the United States, 1900-1975" can be obtained for 10 cents from Sales and Distribution Office, U. S. Department of Commerce, and Dept. of Commerce field offices.

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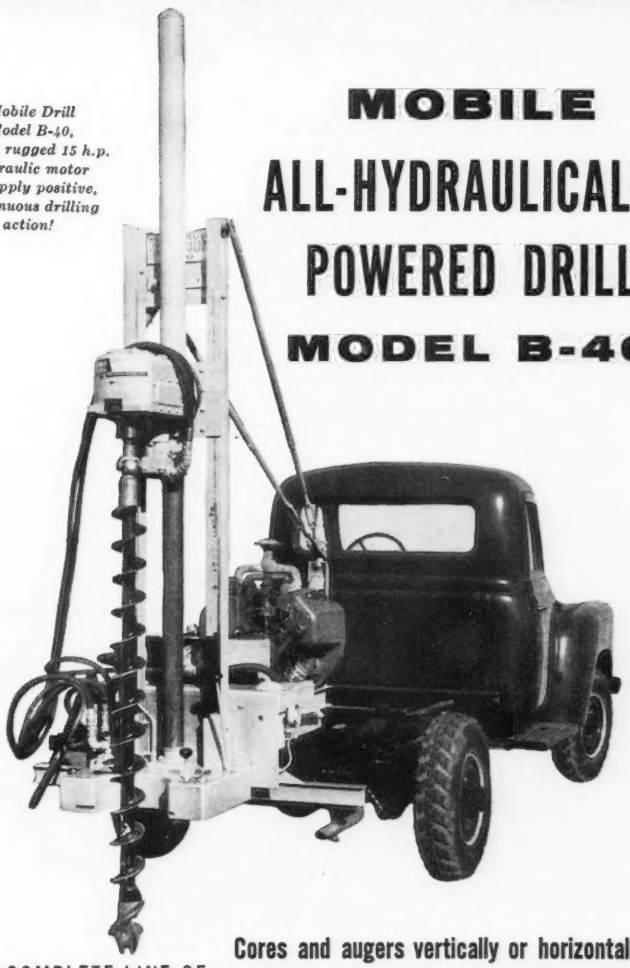
ALL-HYDRAULICALLY POWERED DRILL

MODEL B-40

Mobile Drill Model B-40, with a rugged 15 h.p. hydraulic motor to supply positive, continuous drilling action!



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Light, powerful, low-cost drilling . . . yours, with the new Mobile Drill Model B-40. This one-man-operated rig easily mounts or dismounts on the front, rear, or side of *all* vehicles, including wheel or crawler tractors. Cores with air *or* water to 200', augers to 75' in *minutes*. The B-40 quickly converts to *any* degree in a 360° angle, cuts costs on underground water, gas, and power-line installations. Light enough for air transport to remote areas, powerful enough for a complete range of tough exploratory jobs. Never before has such a LOW COST drill with such amazing power and versatility been offered. Write, 'phone, or wire today for complete information!

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INVESTIGATE!

MODEL B-27

● **Light! Powerful!** Field proven for exploratory work in unconsolidated formations. Mounts on Willys vehicles P.T.O. driven. America's most outstanding light, portable rig.

MODEL B-35

● A convertible drill for vertical-horizontal work, featuring a new **safety** hydraulic clutch. Willys mounted, operated by P.T.O.

MODEL B-36

● A tough, portable rig for heavier formations and P.T.O. operated. Mounts on any 4-wheel drive International or Dodge Power Wagon.

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● **Heavy-duty!** Operated by Ford Industrial Power Plant. Built to withstand terrific torque of toughest formations. Adaptable to a really extensive list of uses.

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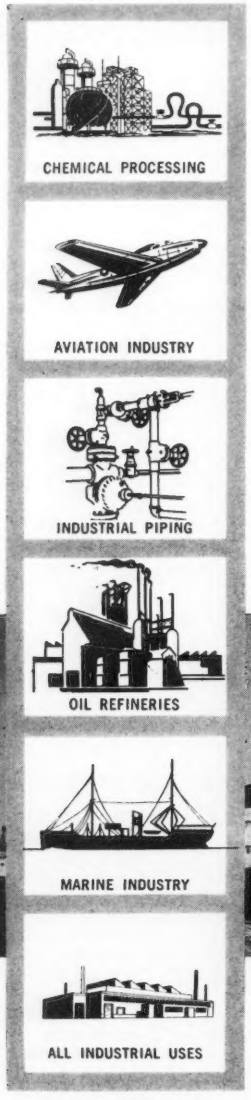
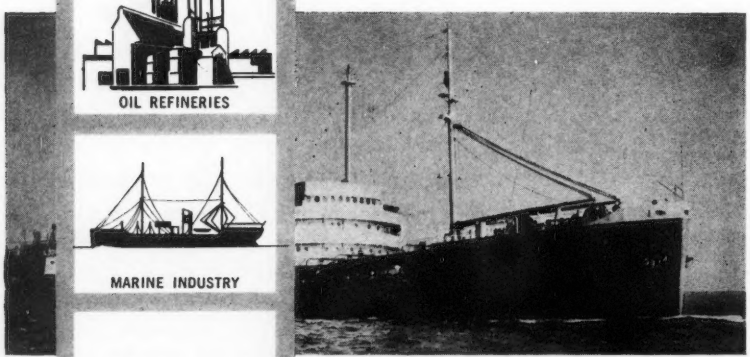


The Niphos Process is an unusual low-cost method for the application of nickel-alloy as a coating or brazing material on ferrous metals. Superior abrasion and acid resistant qualities of nickel are provided in a relatively non-porous coating by this process. Applied rapidly like paint, and fired, the Niphos Process requires no special equipment. Coating has a 100% bond to the base material...doesn't spall, flake or peel... has an optimum hardness of 38 to 42 Rockwell C...is thoroughly heat resistant. Remember, you can eliminate costly corrosion problems *fast* with the Niphos Process. Find out today, how you can use Niphos to *your* advantage.



The effectiveness of the Niphos coating was proved in a recent test aboard the oil tanker S.S. Bulk Star. A standard section of pipe was coated with the Niphos Coating, and installed in a section of the heating coils in a cargo tank, and subjected to the severe corrosive action of alternating loads of hot sour crude oil and salt water ballast. After a year's constant service the Niphos coated pipe showed almost no sign of corrosion.

See the unusual Niphos exhibit at Booth #11, the Corrosion Show, March 12-16. Hotel Statler, New York City.

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NATIONAL, REGIONAL MEETINGS and SHORT COURSES

1956

Mar. 12-16—NACE 12th Annual Conference and Exhibition, Statler Hotel, New York City.

May 3-4—Spring meeting, Southeast Region, Atlanta, Ga.

May 9-10—Niagara Frontier Section-University of Buffalo Chemical Industry Symposium, University of Buffalo, N.Y.

Oct. 16-17—Northeast Region meeting, Philadelphia.

Oct. 23-26—South Central Region, Gunter Hotel, San Antonio, Texas.

1957

Mar. 11-15—NACE Annual Conference, Kiel Auditorium, St. Louis, Missouri.

1958

Mar. 17-21—NACE Annual Conference, Civic Auditorium, San Francisco, California.

1959

NACE Annual Conference, Sherman Hotel, Chicago, Illinois.

SHORT COURSES

1956

Apr. 3-5—Corrosion Control Short Course, University of Oklahoma.

Apr. 18-20—Conference on Marine Corrosion and Fouling Problems, Scripps Institution of Oceanography, LaJolla, Cal.

BACK ISSUES of CORROSION

Years 1945-52 Inclusive Are Now Sold for

$2

per copy, postpaid

Single copies or multiple copies of Corrosion published during the years 1945, 46, 47, 48, 49, 50, 51, 52 now cost $2 each. Prospective purchasers are advised to inquire about availability of copies because many issues are completely exhausted. Remittances must be in advance for purchases aggregating less than $5.

NATIONAL ASSOCIATION of CORROSION ENGINEERS

A. B. Campbell, Executive Secretary
1061 M & M Bldg. Houston 2, Texas

GENERAL NEWS

Applachian Course Aims At Training Technicians

Training technicians in corrosion control is the aim of the Appalachian Underground Corrosion Short Course scheduled June 11-13 on the campus of West Virginia University, Morgantown, W. Va. The School of Mines of the university is giving the course which has the acceptance of the American Gas Association and the indorsement of the National Association of Corrosion Engineers.

The school aims to give an opportunity to those interested to acquaint themselves with the principles of and latest developments in the field of corrosion mitigation. Subjects on the program are: Prevention, testing, cathodic protection, coatings, design, stray current and special topics. Administration of the course will be patterned after that of the Appalachian Gas Measurement Short Course held over a period of 18 years.

The following were named chairmen of the indicated committees: General, Frank E. Costanzo, Manufacturers Light and Heat Co., Pittsburgh; Rules, C. M. Rutter, Equitable Gas Co., Pittsburgh; Program, C. A. Erickson, Peoples Natural Gas Co., chairman and Charles L. Dey, Koppers Co., Inc., Pittsburgh, vice-chairman;

Publications, W. J. Kretschmer, Columbia Gas System Service Corp., Columbus, Ohio; Exhibits, Percy L. Knott, Dearborn Chemical Co., Pittsburgh and Robert H. Edele, W. Va., University; Publicity, William R. Curley, Stuart Steel Protection Corp., Mansfield, Ohio; Registration, R. E. Hanna, Jr., W. Va., University.

BOOK REVIEWS

Modern Physics. By Robert L. Sproull. 491 pages, 5¾ x 9 inches, cloth. January 4, 1956. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. Per copy, $7.75.

The author, associate professor of physics at Cornell University, is editor of the Journal of Applied Physics and a consultant. The book is an analytical approach to aspects of twentieth century physics that are of greatest engineering interest. Crucial experiments in the field, elementary theory underlying the properties of atoms, molecules, solids and nuclei and development of an understanding of physics as a practical means of assessing the properties of materials, processes and instrumentation are covered.

Chapter headings include: Fundamental particles, wave-particle experiments, molecules, imperfections in solids, applied nuclear physics. Appendices include periodic table and atomic weights, conversion of mks to cgs units. There is a subject index.

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Indexes to Corrosion's Technical Section, Technical Committee Activities Section and Corrosion Abstract Section are published annually in the December issue.

Agenda Given for Gordon Research Corrosion Conference at Colby Junior College July 16-20

J. J. Harwood, office of Naval Research, Navy Dept., Washington, D. C. is chairman of the Gordon Research Conference on Corrosion to be held July 16-20 at Colby Junior College, New London, New Hampshire. W. D. Robertson is vice-chairman. Mr. Harwood is a member of the NACE Editorial Review Sub-committee and active in technical committees of the association.

The conference is held for the purpose of stimulating research in universities, research foundations and industrial laboratories. Informal meetings are held, including lectures and free discussion groups. No publications issue from the meetings.

Requests for attendance or additional information may be addressed to W. G. Parks, Director, Dept. of Chemistry, University of Rhode Island, Kingston, R. I. Applications for attendance must include the institution or company by whom employed and type of work in which interested. Attendance is limited to 100.

The scheduled program is:

Monday, July 16

Recent Advances in Electrochemistry, Norman Hackerman, chairman.

Electrochemistry of Metals, R. Piontelli.

The Adsorption of Polyelectrolytes on Mercury Surface, D. C. Grahame and I. R. Miller.

Recent Developments and Current Research in Fused Salt Electrolysis, A. J. Kolk.

Panel Session: Implications of Progress in Electrochemistry to Corrosion.

Tuesday, July 17

New Researches in Passivity, M. Cohen, chairman.

Some Aspects of Passivation, R. Speiser.

Passive Films on Iron, H. H. Uhlig.

Passivity of Iron, M. Cohen.

Panel Session: Mechanism of Passivity.

Wednesday, July 18

Nucleation of Localized Corrosion, J. Petrocelli, chairman.

The Probability Nature of Pitting Corrosion, P. M. Aziz.

Structure Dependent Nucleation of Chemical Reactions at Metal Surfaces, W. D. Robertson.

Nucleation of Corrosion in Stainless Steel, M. A. Streicher.

Panel Session: Nucleation of Corrosion Reactions.

Thursday, July 19

Kinetics of Corrosion Reactions, W. D. Robertson, chairman.

Kinetics of Heterogeneous Reactions, A. J. DeBethune.

Some Studies of the Kinetics of Corrosion Reactions, A. C. Makrides.

Corrosion by Liquid Metals, L. Epstein.

The Phenomena of Liquid Metal Corrosion, W. D. Manly.

Friday, July 20

Fundamentals of Protective Coatings, E. R. Allen, chairman.

The Mechanism of Protective Film Formation, M. Bloom.

Polymer Resins and Their Metal Complexes in Adsorption and Adhesion, F. Eirich and R. Ullman.

Other Gordon Conferences Of Corrosion Interest

Several conferences among the Gordon Research Conferences sponsored by the American Association for the Advancement of Science are of interest to corrosion workers. They include:

At Colby Junior College: June 18-22, petroleum; June 25-29, separation and purification; July 2-6, polymers; July 16-20, corrosion; July 30-Aug. 3, elastomers.

At New Hampton School: June 11-15, organic reactions and processes; June 18-22, metals at high temperatures; July 16-20, organic coatings; July 23-27, chemistry and physics of metals; Aug. 20-24, statistics in chemistry and chemical engineering.

At Kimball Union Academy: June 16-22, stream sanitation; July 9-13, solid state studies in ceramics; July 23-27, chemistry at interfaces; July 30-Aug. 3, ion exchange; Aug. 6-10, high pressure research; Aug. 27-31, glass.

Dillon Is on Beaumont AIChE-ACS Program

Corrosion and Metallurgical Factors in the Failure of Process Equipment by Paul Dillon, Carbide and Carbon Chemicals Co., Texas City will be one of the technical papers given during the Friday, March 9 Third Annual Technical Meeting of Sabine Area Section, American Institute of Chemical Engineers and the Texas-Louisiana Gulf Section, American Chemical Society. The session will be held at Lamar State College of Technology, Beaumont.

Other technical papers relate principally to matters of interest in the petroleum industry.

Dallas Southwestern Paint Convention Set May 10-12

Technical papers will be presented May 12 at the Dallas Statler-Hilton Hotel during the Southwestern Paint Convention to be held there May 10-12. Subjects of interest to the paint industry will be included.

A program of entertainment for ladies has been arranged and there will be a golf tournament and a banquet and dance. Walt McKinney, Box 7025 Dallas, is in charge of registrations.

Spectrographic Standard Samples of Stainless Steel Are Now Available from NBS

THE NATIONAL Bureau of Standards has announced the availability of six new standard samples of stainless steel. The samples, carefully analyzed and certified for composition, are designed for calibrating and checking spectrochemical methods of analysis. Together with a set of three spectrographic standards issued earlier, NBS standards now provide certified concentration values for determining most of the elements encountered in the analysis of stainless steels.

The new stainless steel standards are certified for concentrations of six major and minor elements: Manganese, silicon, copper, nickel, chromium and molybdenum. Samples are available in two forms: rods 7/32-inch in diameter and 4 inches long, and rods ½-inch in diameter and 2 inches long. Both forms serve as electrodes for spark excitation in spectrochemical analysis. The three stainless steel standards issued previously are certified for nine trace elements: Aluminum, boron, copper, molybdenum, columbium, lead, vanadium, tungsten and zinc. These are available in the form of rods 7/32-inch in diameter and 4 inches long.

Long in Preparation

Since spectrochemical methods of analysis are both fast and accurate, such methods have been increasingly applied to the analysis of complex steel alloys. Anticipating the growing need of industry for suitable standards, the bureau began preparing the stainless steel samples several years ago. Six heats of metal were contributed by the Uddeholm Company of Sweden, which prepared the steels to desired composition and fabricated the metal into rods. A grant from the American Iron and Steel Institute assisted the bureau in homogeneity testing and analysis. Chemical analyses were made by four cooperating laboratories: Allegheny-Ludlum Steel Corporation, Armco Steel Corporation, Wilbur B. Driver Company and NBS.

The rods have a uniform grain structure resulting from hot-rolling and annealing the cast metal. The surfaces of the rods were finished by centerless grinding. The homogeneity of the rods, both in cross and longitudinal sections, was studied by spectrochemical analysis at the bureau and was found satisfactory with respect to the concentrations of the certified elements.

The standards can be applied directly to the analysis of stainless steel rods prepared in a similar manner and with similar dimensions. However, when the standards are applied to the analysis of steel samples prepared by other procedures, adjustments may be required to correct for variations introduced by physical differences.

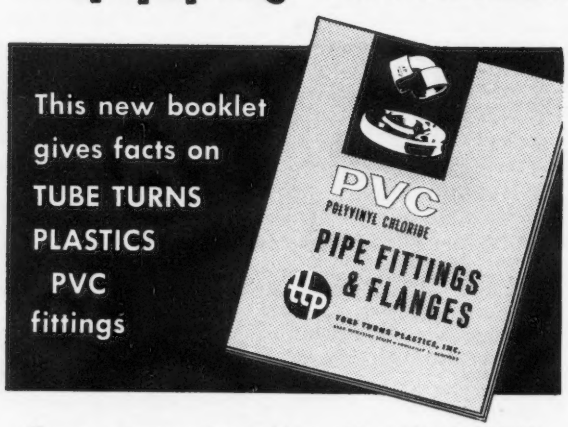
The stainless steel standards may be obtained from the National Bureau of Standards for a fee of $8.00 each. A provisional certificate supplied with the standards gives average values of the analyses reported by the cooperating laboratories. The compositions and sizes of the standards are given in Table 1. In addition to the elements now certified, the standards also contain aluminum, columbium, tin, titanium, vanadium and tungsten, some of which may be certified at a later date.

TABLE 1—Composition of NBS Spectrographic Standard Samples of Stainless Steel

Sample	Numbers[1]	Mn	Si	Cu	Ni	Cr	Mo
		%	%	%	%	%	%
445	845	0.77	0.53	0.065	0.28	13.30	0.92
446	846	.53	1.20	.19	9.10	18.37	.43
447	847	.23	0.37	.19	13.26	23.73	.059
448	848	2.10	1.25	.16	0.52	9.10	.33
449	849	1.62	0.68	.21	6.62	5.48	.15
450	850	—	0.12	.36	24.8	2.99	—

[1] Sizes: 400 Series, rods 7/32-inch in diameter, 4 inches long.
800 Series, rods ½-inch in diameter, 2 inches long.

Stop piping corrosion!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PVC
POLYVINYL CHLORIDE
PIPE FITTINGS & FLANGES
TUBE TURNS PLASTICS, INC.

You can solve corrosion problems with unplasticized PVC piping—outlasts and costs far less than metal systems for handling many types of corrosive materials. New booklet gives properties and applications of PVC systems, describes PVC pipe fittings and flanges made by Tube Turns Plastics, Inc., the only source for injection molded PVC products. Produced by the exclusive Hendry process, these PVC fittings are considerably stronger than fittings made by conventional processes. Write Tube Turns Plastics, Inc., Dept. PG-3, 2929 Magazine Street, Louisville 11, Kentucky.

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Widespread Effect of Air Contamination Reviewed

The widespread effect of air contaminants on health, legislation, industry and vegetation is emphasized in the data contained in the February issue of "Report," a publication of the Air Pollution Control District of Los Angeles County, Cal. The county has been faced with one of the most severe air pollution problems in the nation for several years and has made an extensive study of pollutant sources and effects.

Among the reports included is one in which it is indicated that the state of California may be asked to require allocation for domestic use of 177 million cubic feet of natural gas daily expected to be delivered to the area by a new pipe line from Texas.

In 1955 there were 2974 court cases involving violations of smog regulations with the percentage of convictions being 92.3 percent.

Los Angeles industry spent nearly $10 millions on air pollution control equipment during 1955.

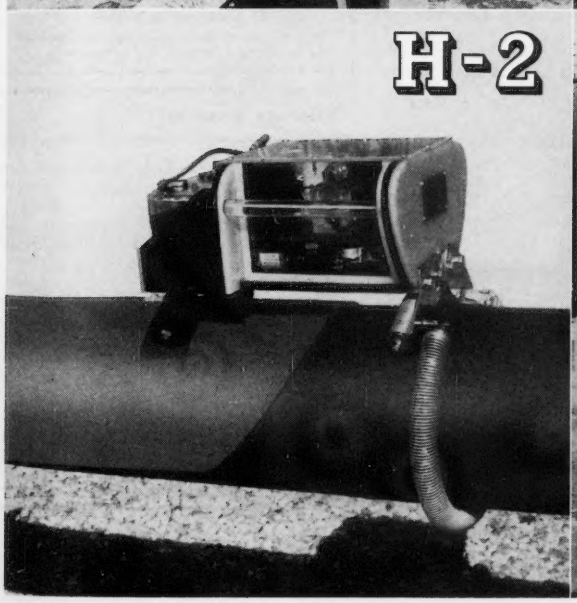
Emissions from refineries in the Los Angeles basin are being re-evaluated by inspectors, including some operating in Navy Blimps.

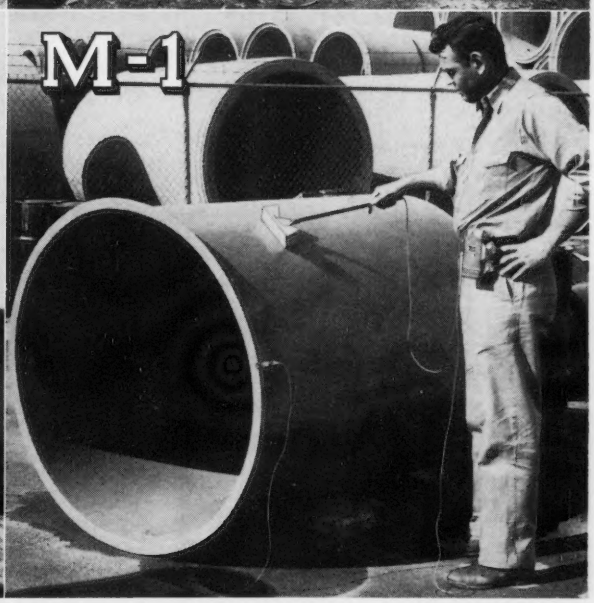
The effect of improved maintenance on the smog-emissions from private automobiles is being tested on 1000 cars.

Concern is expressed over the possibility that increased demands for electrical power in the Los Angeles area will lead to construction of new steam power plants which if present operations are continued unchanged may increase the volume of sulfur dioxide emitted from the present 502 tons daily to over 1300 tons by 1970. Seven new power plants are in the planning stage now.

Container Research Meeting

Achievements of the U. S. armed forces in container research, development and applications engineering and information on the Army's radiation sterilization program will be covered in a meeting at Statler Hotel, Boston April 11-13. The Research and Development Associates Food and Container Institute annual meeting will be held there on that date.





You Can't Patch It - If You Can't Find It!

These Electrical Detectors Show Up Weak Spots in Protective Coatings

E-4 Portable, pack-type, all-purpose, holiday detector with wet-cell battery output adjustable from 2500 to 20,000 volts D.C. Inspection electrodes for pipe sizes 2 to 30-in. diam. also steel brush for surface checking. E-4 checks dry surfaces only.

E-P Holiday detector similar to E-4 but suitable for testing either wet or dry surfaces. The best general-purpose holiday detector made. Comes in sturdy carrying case with battery charger.

H-2 Pipeline "Jeep" which will rapidly field test the coating on any transmission pipeline. Needs no trailing ground wire. Maintains a constant electrical potential on the pipeline at all times. Signals coked or burned spots in coatings as well as holes. This unit has seen service in all parts of the world.

M-1 Belt-mounted inspection instrument weighing but 3 lbs. Wand holds cellulose sponge which is dampened with plain water. When wiped over any painted or coated surface up to 10 mils thick it will signal pinholes or breaks by bell signal.

BEAT NATURE TO THE PUNCH

Your protective coatings on metal or concrete are only as good as their weakest points. Nature will seek out pin-holes and thin spots caused by air bubbles, dirt, coke or rust in the protective coating. Be safe and check pipe or other painted surfaces before putting them into severe service. A Tinker & Rasor electrical detector can quickly find the weak spot in your coating—wet or dry. It can do so rapidly and efficiently and without physical damage to the coating in any way. There is a T & R Holiday Detector for every surface testing job + each is fully guaranteed.

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Equipment Services NEW PRODUCTS Materials Literature

Isotope Products, Buffalo, N. Y. describes the various types of gamma cameras used in inspection of weldments, pipelines, tanks and other metal structures in an "Isotope Newsletter published by the firm." Also discussed is the cost of atomic energy to generate power.

•

Haynes Stellite Co., a division of Union Carbide and Carbon Corp., Kokomo, Ind., has reprinted from the magazine Welding Journal an article, Weldability of Wrought High-Alloy Materials. Resistance to corrosion and high temperatures plus oxidation, stresses and mechanical shocks are discussed in the paper.

•

Lanco Apparatus News, published by Arthur S. La Pine & Co., 6001 S. Knox Ave., Chicago 29, Ill., is a 12-page illustrated catalog of the firm's laboratory equipment. Flash evaporators, sink traps, stirring equipment and other equipment are listed. In another announcement, the firm states that L. D. Long will represent them in Louisiana and the Gulf Coast. He will maintain offices in New Orleans.

•

McCullough Tool Co., Box 2575, Houston 1, Tex. and Pennsylvania Salt Manufacturing Co., 3 Penn Center Plaza, Philadelphia 2, Penn. have collaborated on the development of a high speed chemical cutting tool for cutting and perforating pipe inserted in oil wells. The chemical used is a halogen fluoride which cuts through pipe in a fraction of a second, leaving no jagged edges nor burred holes.

•

R. N. Rhoda has been appointed head of the Platinum Metals Section of the International Nickel Company's Research Laboratory at Bayonne, N. J. He succeeds **Ralph H. Atkinson,** who retired after 30 years' service with Inco.

•

Ralph W. Rawson has joined Fansteel Metallurgical Corporation as chief engineer in charge of the company's new Centralized Engineering Department. He recently has been, as a commander in the U. S. Navy, director of industrial planning for the Bureau of Aeronautics at Wright-Patterson Air Force Base, Dayton, Ohio.

•

Design of Magnetostriction Transducers, 38-page and cover booklet published by The International Nickel Co., Inc., 67 Wall Street, New York 5, N. Y. is available from the company's Reader Service Section.

Dealkalization—Its Application in Water Treatment, Technical Reprint T-142 from National Engineer, November 1955 can be obtained without cost from Graver Water Conditioning Co., 216 West 14th St., New York.

•

Sequestrene Bibliography (1953-54) is available on request from Geigy Industrial Chemicals, 89 Barclay St., New York 8, N. Y.

(Continued on Page 106)

CORROSION ENGINEER or CHEMIST

M.S., PhD physical or electro chemist or chemical engineer for research and development in corrosion. Position includes the analysis and mitigation of current corrosion problems and the development and investigation of inhibitor additives as well as some fundamental studies of corrosion reactions. Excellent laboratory facilities. Reply in detail to:

Mr. T. A. Abbott, Manager
Engineering Research Dept.
Standard Oil Company (Indiana)
Whiting, Indiana

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MAJOR OIL COMPANY has openings for Equipment Inspectors for refinery in Middle East.

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Protective Coating Chemist—Thoroughly experienced in all inhibitive and protective metal paints. Eighteen years formulating for variety of atmospheres. Masters degree, member several societies, currently group research leader. CORROSION, Box 56-7.

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Senior Inspector:

Minimum ten years' experience in design or inspection of petroleum processing plants and equipment, of which five years must have been in inspection work entailing general knowledge of all facilities.

Inspector:

Minimum five years' experience maintaining and inspecting pressure vessels and oil handling equipment. Thorough knowledge of API and ASME codes for fired and unfired pressure vessels and piping is required.

Salary $9,000 to $11,000 depending on training and experience. Plus a living allowance of approximately $3,600 paid in Saudi riyals.

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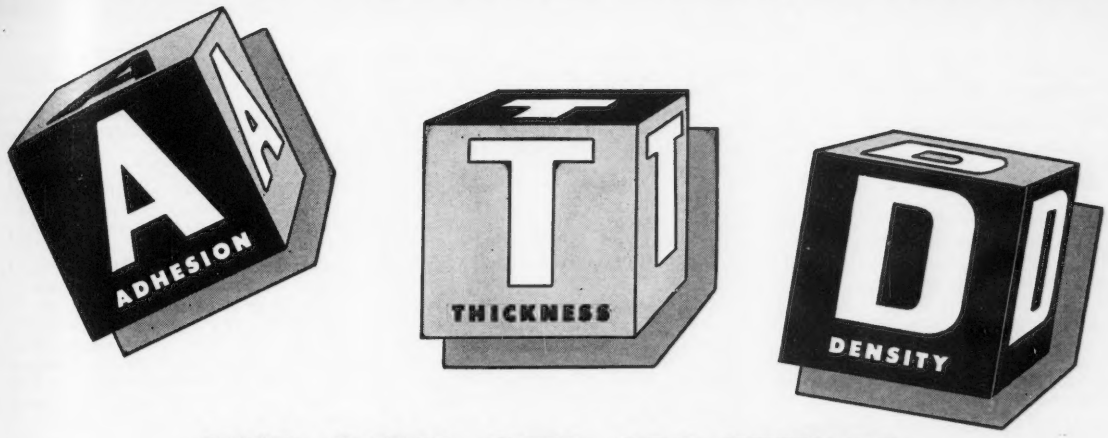

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AKRON 9, OHIO

92E

NEW PRODUCTS

(Continued From Page 104)

Alloys for Heat Exchanger Problems, a 28-page illustrated booklet giving typical installations of cupro-nickel or nickel-copper alloys in power plants is available from Reader Service Section, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

•

Superior Tube Company is building a half million dollar mill and office building replacing its present Waponeta, Ohio plant. Increased production of small tubing and electronic parts is anticipated in the new plant.

•

Cellulose Section at American Viscose Corp. Research and Development Div., Marcus Hook, Pa. has been reactivated. Wayne A. Sission has been named leader of the section.

MEN in the NEWS

Roman F. Geller, chief of the Porcelain and Pottery Section of the National Bureau of Standards has retired after 35 years of service. He will continue to serve the NBS Mineral Products Division as chairman of its editorial committee and as a ceramic consultant on a part time basis. He is author of 65 papers on ceramics and whiteware and holds a patent for a thoria heating element. He is an alumnus of the University of Michigan.

•

John G. Dean, chemical and metallurgical consultant has been retained by Climax Molybdenum Co. to advise on aspects of the company's expanded chemical program. Dr. Dean specializes in heavy metals, especially in their catalytic applications and uses in hydrometallurgical extraction. He has a PhB from Brown University and PhD from Columbia.

O. E. "Neal" Thompson has been appointed assistant salesmanager of T. D. Williamson, Inc., Tulsa manufacturer of pipe line equipment. He joined the company in 1948 and is a 4-year Navy veteran of World War II.

•

R. R. Hughes of R. R. Hughes Co., Seattle has been named Pacific Northwest representative for T. D. Williamson, Inc., Tulsa manufacturers of pipeline equipment. He formerly was vice-president and general manager of Industrial X-Ray Engineers, Tulsa. **E. C. "Paul" Robinet** of Cameron Engineering Co., Los Altos, Cal. and **R. M. Riddell,** Pasadena, Cal. have been named Northern and Southern California representatives respectively for Williamson.

•

C. J. Lockwood has been named executive vice-president of Socony Paint Products Co., a subsidiary of Socony Mobil Oil Co., Inc. He succeeds **F. A. Walters,** who retired Dec. 30 after 43 years' service with the company. Mr. Lockwood was born in Manor, Texas and graduated from University of Texas in 1926 as a chemical engineer. He was superintendent of Magnolia Petroleum Company's Fort Worth refinery, was superintendent of Socony Paint Products' plant at Beaumont, later becoming vice-president and general manager of the Beaumont operations.

•

E. Alfred Burrill, High Voltage Engineering Corp., Cambridge has been named chairman of committee I on Recommended Radiographic Practice of Committee E-7 on Nondestructive Testing, ASTM.

•

Fred Lohse has been appointed technical assistant to the manager of the Chemicals Division of Kaiser Aluminum & Chemical Corp. He joined Kaiser in 1939 as a process engineer for Permanente Cement Co. He was responsible for the design and construction of the sea water magnesia plant at Moss Landing, Cal.

•

Harmon H. Plumb, a physicist, has joined National Bureau of Standards cryogenic physics laboratory. He will work to establish low temperature scales covering the range from 4 degrees K to 20 degrees K. He holds a PhD from Northwestern University.

•

L. B. Kuhns and **B. J. Fletcher** have been named assistant chief engineers for Aluminum Company of America. Mr. Kuhns is chief construction engineer and Mr. Fletcher is chief hydraulics engineer.

•

Bruce H. Billings, director of research at Baird Associates, Inc., Cambridge has been named general manager.

•

Maj. Gen. Louis W. Prentiss has been made commanding general of the Engineer Research and Development Laboratories, Fort Belvoir, Va. **Col. H. F. Sykes, Jr.,** who has commanded the laboratories since 1954 has been named director and the agency has been designated a Class II activity directly responsible to the chief of engineers.

•

Thomas E. Deger has been promoted to position of Acting Director of Organic Research, Pennsylvania Salt Manufacturing Co.

•

E. K. Wilkins has been made vice-president in charge of construction and **W. H. Colquhoun** vice-president in charge of engineering of Ebasco Services, Inc., New York engineering consulting firm. Mr. Wilkins has been with Ebasco since 1922 and Mr. Colquhoun, a graduate of Rensselaer Polytechnic Institute has been with the company since 1941.

•

W. F. Stark has been appointed vice-president of Promat Division of Poor and Co. succeeding **Allan E. Chester,** recently deceased. **William F. Mooney** has been named vice-president in charge of sales.

•

Donald K. Wright has been named manager, By-Products Sales, American Smelting and Refining Co. He succeeds **Leslie G. Matthews,** who retired December 31. Wright has been with the company since 1924.

•

Edwin A. Lampman, 70, retired January 3 after about 23 years with Acheson Colloids Co., Port Huron, Mich.

•

Arnold J. Herrmann, whose continuous service with American Cast Iron Pipe Company, Birmingham, Ala. began in 1914, has been elected executive vice-president of the company. For 21 years he was manager of the firm's Kansas City office. **J. W. McKay** has been elected vice-president, sales manager and secretary of the firm. He has been with the company since 1936. Other promotions at Acipco include: **James B. Hill,** assistant salesmanager; **Paul W. Green,** manager Kansas City office; **Leonard C. Parnell,** manager Minneapolis Sales Office; **Robert C. Bramlette,** assistant manager of the Chicago sales office.

•

Howard S. Cullman, honorary chairman of the Board of Commissioners of the Port of New York Authority has received the 1956 Stevens Honor Award. The award, in the form of a medallion, was presented at the annual dinner of Stevens Institute of Technology engineering college's alumni association February 3.

Hot sprayed mastic coatings are denser, more durable

Pinholing of protective coatings results from the delayed evaporation of trapped solvents. By substituting **heat** for thinner, hot spray produces a denser, less porous film that won't pull at the edges, flows out smoothly. Results: greater protection at lower cost. Spee-Flo Powermastic Heaters permit year-round application of heavy mastic coatings. For literature or on-the-job demonstration, write: Spee-Flo Company, Dept. C-14, 720 Polk, Houston, Texas.

CORROSION ABSTRACTS

Index to CORRODION ABSTRACTS

Vol. 12 March, 1956 No. 3

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1. GENERAL

1.2 Importance

1.2.5, 8.3.5

Toxicity of Metals. A. D. MERRIMAN. *Metal Treatment & Drop Forging*, **22**, No. 114, 127-131+ (1955) Mar.

Use of metals in preparation, cooking, storage and transport of food and drink is covered. Effect of metals on flavor and color of food and the possible injurious effect for human consumption are considered. Possible sources of contamination of food by metallics and the degree of "pick-up" are discussed while an indication of the harmful dosages is given of common metals in use. Metals considered are copper, aluminum, iron, stainless steel, tin and lead.—INCO. 9588

1.4 Bibliographies and Indexes

1.4

Bibliographic Survey of Corrosion, 1950-51. Book, 1955, 430 pp. National Association of Corrosion Engineers, 1061 M & M Building, Houston 2, Texas.

The fourth in the series of bibliographies of corrosion literature published by NACE. Abstracts are for articles and books published in the biennium 1950-51. Each article is abstracted with title, names of authors, volume, number of issue, inclusive pages, year of publication and date of issue plus an abstract. Abstracts are from the same 30 agencies that authorize NACE to use their abstracts and range from the indicative to the informative.

The book includes 4454 abstracts, indexes 4047 authors, has cross-indexing after each topical subdivision. Topics are those in the NACE Abstract Filing System Index. There also is a comprehensive alphabetical subject index. 9541

1.6 Books

1.6, 1.5, 6.5

Metallkunde. (In German.) WILLIAM M. GUERTLER. Book, 1954, 204 pp. Gebruder Borntraeger, An Der Rehwiese 4, Berlin-Nikolasee, Germany.

Essentially a text on the characteristics of metals, this well-illustrated book describes metals, differences among metals, how metals are used, selection of best metals for specific uses, characteristics of crystal structure, atomic structure, melting characteristics, microscopy, strength, characteristic and numerous other data.

It is fully illustrated with diagrams showing theoretical arrangements of internal structure, crystal size and shape, with graphs of data on mechanical characteristics.

There is an alphabetical subject index. 9691

2. TESTING

2.2 On Location Tests

2.2.1, 2.3.1

Corrosion (Test Specimens). M. G. FONTANA. *Ind. and Eng. Chem.*, **46**, No. 4, 91A-93A (1954) April.

Procedures are outlined for laboratory, plant, and field corrosion tests. Information is presented to aid persons in testing and in the use of results obtained.—INCO. 9442

2.2.2, 1.6, 4.2.1

Atmospheric Corrosion of Metals at Various Sites in Nigeria; Comprehen-

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JOHN CRERAR LIBRARY 86 East Randolph St., Chicago 1, Ill.

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Neither NACE nor the sources listed below furnish reprint copies.

ALL—The Abstract Bulletin, Aluminium Laboratories, Ltd. P. O. Box 84, Kingston, Ontario.

ATS—Associated Technical Services Abstracts, Associated Technical Services, P. O. Box 271, East Orange, N. J.

AWWA—Journal, American Water Works Association, Amer. Water Works Asoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CBEC—Centre Belge d'Etude de la Corrosion (CEBELCOR), 17 re des Drapiers, Brussels, Belgium.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

IIM—Transactions, The Indian Institute of Metals, 23-B, Notaji Subhas Road, P. O. Box 737, Calcutta, India.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguro-ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana, Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

SE—Stahl Und Eisen, Verlag Stahleisen, M. B. H., Dusseldorf, August-Thysen Str. 1. Postscheck Koln 4110, (22a) Dusseldorf, Germany.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. 34 Berkeley Square, London W.1.

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sive Report on Trials from August, 1952 to March, 1954. H. R. AMBLER. Gt. Brit. Tropical Testing Establishment, Port Harcourt, Nigeria, Report No. 352, June, 1954, 93 pp.

Panels of ingot iron, mild steel, copper steel, brass, zinc, and aluminum were weathered at various sites 50 yd. to 520 miles from the sea; and corrosion rates were measured gravimetrically and compared with those reported from non-African marine sites.

There was no evidence of any systematic difference in the corrosion rate of steel between day and night or between seasons. Where salinity was the governing factor, steel corroded at a roughly constant rate. In regions of high humidity but low salinity, the corrosion rate fell off after about one month, and after 6-9 months corrosion almost ceased. In general, zinc behaved like steel.

The corrosion rate of brass was roughly constant at all sites; however, the rate was faster in the dry season. Both brass and aluminum were more affected by inductrial pollution than by salt. Corrosion was greatly reduced on all metal surfaces protected by muslin from solid particles, whether salt nuclei or particles of sulfur pollution. 9353

2.2.2, 1.7.1

Report of A.S.T.M. Advisory Committee on Corrosion. American Society for Testing Materials, Preprint No. 67, 1954, 7 pp.

Details are given of specimens exposed at 7 A.S.T.M. atmospheric-test sites during 1953 by 5 ASTM Committees and by other societies. Details are also given of a number of exposure-test programs planned by 6 ASTM Committees and two other bodies. 110 specimen racks, providing space for 7700 4 x 6 in. specimens, are being constructed from Monel or stainless steel for distribution to the various sites. Details of construction of these frames are shown. Details are also shown of a galvanized steel-pipe frame support for exposing test specimens.—MA. 9333

2.2.2, 4.2.8, 6.4.2

The Behavior of Aluminum Exposed for Long Periods to a City Atmosphere. (In Italian.) C. PANSERI AND A. GRAGNANI. *Alluminio*, **23**, No. 6, 627-637 (1954) Dec.

Chemical analysis and mechanical and micrographical tests of samples of 50-year-old low-purity roofing sheets show excellent behavior with pitting of corroded zones held below 0.1 mm. Photographs, micrographs, tables. Six references.—BTR. 9566

2.2.2, 6.6.8

Three Years' Outdoor Weather Ageing of Plastics Under Various Climatological Conditions. S. E. YUSTEIN, R. R. WINANS & H. J. STARK. ASTM Bull., No. 196, 29-39 (1954) Feb.

Materials investigated include five types of clear transparent sheet plastics, six types of laminated materials, and five types of molded bars; data are for sites located in Panama Canal Zone (tropical), New Mexico (dry desert), New York (temperate), Fort Churchill, Canada (Subarctic), and Point Barrow, Alaska (arctic).—BL. 9481

2.3 Laboratory Methods and Tests

2.3.1, 3.5.9

Corrosion: Testing. M. G. FONTANA. *Ind. & Eng. Chem.*, **46**, No. 8, 77A-79A (1954) Aug.

Effect of temperature on corrosion testing is discussed. A table showing effect of temperature on corrosion of 18-8S stainless steel by 65 percent nitric acid is presented.—INCO 9684

2.3.1, 5.4.5

Methods of Testing the Action of Pigments in Varnishes. (In Italian). C. BIGHI AND G. MANTOVANI. *Metallurgia italiana*, **46**, special supplement to No. 5, 117-118 (1954) May.

Microammeter, electrolytic cell, liquid attack, and industrial corrosive atmosphere tests. Photograph. 7 references.—BTR. 9310

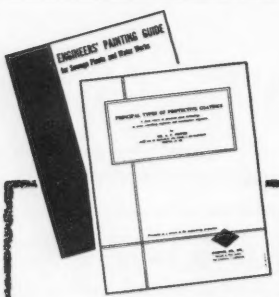
2.3.1, 7.7, 2.5

Basic Climatic and Durability Tests for Components for Radio and Allied Electronic Equipment. British Standard 2011:1954, 16 pp. British Standards Institution, 2 Park St., London, W. 1.

Tests include robustness of terminations, soldering, dry heat, accelerated and long term damp heat, cold, bumping vibration and endurance, salt mist and mould growth. Describes suitable salt mist chamber and method for maintaining 75% relative humidity.—BNF. 9792

2.3.4, 2.3.5, 3.8.4

The Hydrogen Electrode-Silver Chloride Electrode System at High Temperatures and Pressures. M. H. LIETZKE. Oak Ridge National Lab. U. S. Atomic



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Energy Comm. Pubn., ORNL—1741, July 30, 1954, 9 pp.

A knowledge of the behavior of the hydrogen electrode at high temperatures and pressures will ultimately afford a means of measuring the pH of aqueous solutions above 100° C. In the present paper it is shown how theoretical curves can be plotted demonstrating the behavior of the hydrogen electrode-silver chloride electrode system at temperatures up to 250° C and pressures up to 40 atmospheres. The agreement between calculated potentials, which are based on extrapolation of data obtained at lower temperatures, and experimental data obtained directly at the higher temperatures is shown and discussed. A mechanism is proposed to account for deviations between the calculated and experimental values at the higher temperatures and pressures. (auth). —NSA. 9569

3. CHARACTERISTIC CORROSION PHENOMENA

3.1 General

3.1, 5.1

What to Do About Corrosion. CHARLES EMERSON. *Am. Machinist*, **98**, No. 26, 145-160 (1954) Dec. 6.

Discussion of corrosion—what it is, how it forms, where it helps, where it harms, and various ways to combat it, including paints and organic finishes, metal plating, inhibitors, cathodic protection and packaging. Illustrations.—INCO. 9640

3.2 Forms

3.2.2, 7.6.5, 8.10.2

Examination of the Cracks of the Tubes of "Vogelbusch" Evaporating Boilers Used in Alumina Plants. (In Hungarian.) ISTVAN KUROVSZKY. Kohaszati Lapok, **9**, No. 1, 27-34 (1954) Jan.

Investigates tubes in two Hungarian factories Causes of intercrystalline corrosion and elimination of defects. Diagram, tables, micrographs, photographs.—BTR. 9474

3.2.2, 6.2.5, 3.7.3, 3.8.4

Kinetics of Intercrystalline Corrosion of Chromium-Nickel Stainless Steels. (In Russian). V. SH. SHEKHTMAN, M. A. VEDENEEVA, AND N. P. ZHUK. *J. Phys. Chem. U.S.S.R.* (Zhurnal Fizicheskoi Khimii), **28**, No. 12, 2199-2210 (1954) Dec.

Effects of heat treatment, composition and concentration of corrosion medium, cold working, and trace-element content of steel. Special electrical method of investigation. Graphs, micrographs, diagrams, tables. 18 references.—BTR. 9328

3.2.2, 3.7.3, 6.2.5

Corrosion of Stainless Steel in Acid Oxidizing Solutions; New Type of Corrosive Attack on Welded Joints. (In Russian). M. M. KURTEPOV. *Doklady Akad Nauk S.S.S.R.*, **99**, No. 2, 305-307 (1954) Nov. 11.

Corrosion of welded stainless and acid-resisting steel after prolonged exposure to nitric acid—potassium dichromate solution at 100° C is illustrated. An intercrystalline type of corrosion in welded 18-8 stabilized with titanium, niobium, molybdenum, titanium + molybdenum or niobium + molybdenum is shown. Two figures.—NSA. 9473

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3.5 Physical and Mechanical Effects

3.5.8

The Growth of Fatigue Cracks. A. K. HEAD. Australian Aeronautical Research Labs., Report Met. 5, July, 1954, 39 pp. Obtainable from the Chief Superintendent, Aeronautical Research Labs., Box 4331, G.P.O., Melbourne.

A theoretical analysis of the growth of a fatigue crack based on idealized form of crack. The predicted rate of growth is found to be in reasonable agreement with experiment. The theory gives no indication when the crack is formed. A shorter account has already been published.—BNF. 9748

3.5.8, 1.6

Fatigue. Book, 1954, 121 pp. American Society for Metals, Cleveland, Ohio.

Series of educational lectures presented at 35th National Metal Congress and Exposition, October, 1953. "Basic Concepts of Fatigue Damage in Metals," T. J. Dolan (pp. 1-35); "Fatigue Failure Under Resonant Vibration Conditions," B. J. Lazan (pp. 36-76: non-ferrous and ferrous metals); "Fatigue Characteristics of Large Sections," D. J. Harger (pp. 77-121: steels.—BNF. 9762

3.5.8

Fatigue Failures, with Special Reference to Fracture Characteristics. G. A. COTTELL. British Engine Boiler and Electrical Insurance Co. Ltd. Tech. Report, Vol. II, 1954, 221-256.

A general survey. Fatigue crack characteristics; characteristic features of basic crack types (undirectional, alternate or rotary bending, torsion, direct or combined stress); examples of service failures (all ferrous); detection of fatigue cracks (magnetic particles, fluid penetration, etching, radiographic and ultrasonic methods); fundamentals of fatigue failure, stress cycle, endurance, under- and over-stressing, stress concentration, surface condition, effects of corrosion, micro-mechanism of fatigue failure. Short bibliography.—BNF. 9779

3.5.8

Mechanical Failures of Metals in Service. JOHN A. BENNETT AND G. WILLARD QUICK. U. S. Nat'l. Bur. Stand. Circ. No. 550, September, 1954, 36 pp.

After describing the general characteristics of failures due to overloading, fatigue, and stress-corrosion, respectively, Bennett and Quick detail 35 representative examples of failures examined during the period 1940-1951. The examples chosen deal mostly with steel components, but several are of aluminum and copper alloys. It is concluded that fatigue is by far the most common cause of mechanical failure in service, and the effect of notches, holes, etc., as stress-raisers is still not sufficiently appreciated by designers. Careful workmanship is always needed to avoid tool marks, quench cracks, decarburization, etc. Brittle fracture ranks second to fatigue as a cause of failure, particularly in large structures; in these, design should be conservative and care should be taken to use materials having good resistance to brittle fracture over the temperature range expected in service. Corrosion is often a contributory factor to mechanical failure, and the possibility of stress-corrosion of certain copper and aluminum alloys is emphasized.—MA. 9787

3.5.8, 2.3.7, 6.2.3

Fretting Corrosion of Mild Steel in Air and in Nitrogen. I-MING FENG AND H. H. UHLIG. Paper before Am. Soc. Mech. Engrs., Lubrication Activity Div. & Applied Mechanics Div., Semi-Ann. Mtg. Pittsburgh, June 20-24, 1954. ASME Preprint No. 54-SA-6, 1954, 6 pp.; *J. Applied Mechanics*, **21**, 395-400 (1954) December.

Data are presented on fretting corrosion of mild steel using weight loss as a measure of damage. Effects of duration of test, humidity, temperature, slip, pressure, and of frequency and nature of corrosion products are discussed and shown in graphs. Humidity of ambient air was found to be a sensitive variable requiring control. Fretting corrosion of mild steel in moist air is only 55-65% of the weight loss in dry air depending on duration of test. Because of this large difference, all tests were carried out in dry air. Fretting corrosion is appreciably greater below room temperature than above room temperature (up to 150° C.). Weight losses of specimens fretted at 50° C. are approx. 50 percent losses at 0° C. Rate of fretting corrosion in air is constant with time after an initial run-in period during which the rate is temporarily higher. In moist or dry nitrogen, weight losses are much less, although not zero. The greater the relative slip, the greater is fretting damage, and in complete absence of slip no weight loss occurs. Increased pressure or load

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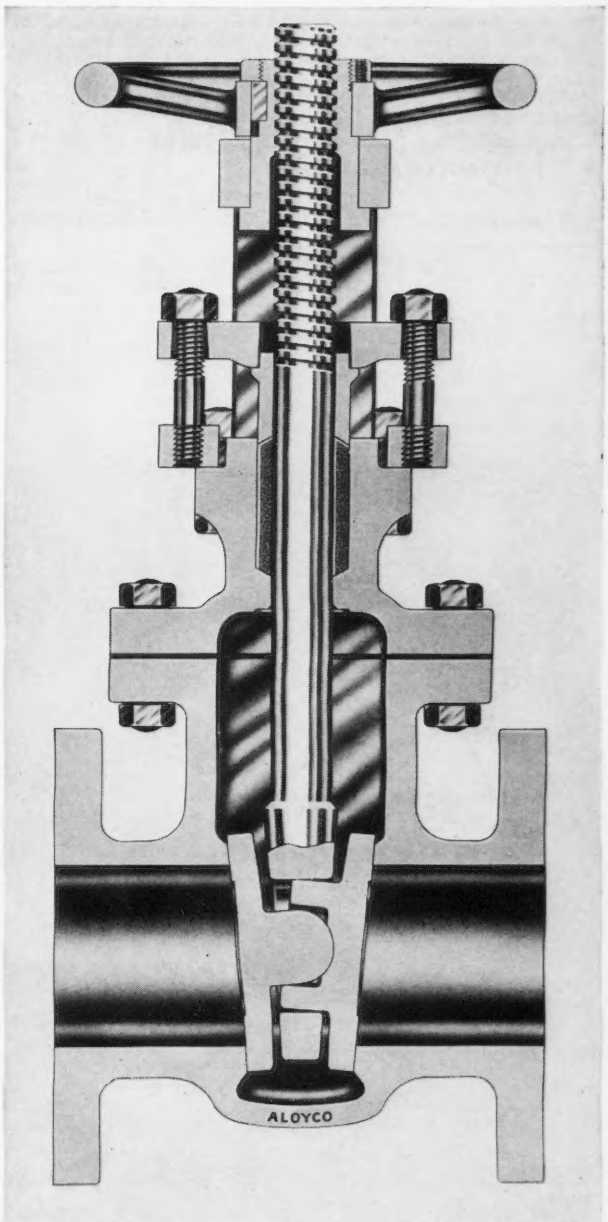

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increases fretting damage. Weight loss is greater the lower the frequency for the same number of test cycles. The frequency effect increases with relative slip, and in nitrogen the frequency effect disappears. 18 references.—INCO. 9752

5. PREVENTIVE MEASURES

5.3 Metallic Coatings

5.3.2, 1.6

The Corrosion Resistance of Hot Dip Galvanized Steel Structures. (In Dutch). Booklet, 1955, 56 pp. Published by Stichting Doelmatig Verzinken, Jan Van Nassaustraat 93, 'S-Gravenhage, Holland.

Information is given on the resistance to corrosion of hot dipped galvanized steel in numerous environments, including atmospheric, fresh and sea water, chemicals and others. Illustrated, tables of data. Alphabetical subject index. 9224

5.3.2, 2.3.7

Structure of Zinc Coatings, Determined by Electrochemical Dissolution. (In German). W. KATZ. *Arch. Eisenhuttenw.*, **25,** No. 7/8, 307-314 (1954) July/Aug.

A study of the electrochemical potentials in sodium chloride/zinc sulfate solution of the alloy layers in hot-galvanized coatings on steel suggested that this might be made the basis of a thickness test for zinc coatings which would be more efficient than the Preece test.—BNF. 9201

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5.3.2, 3.5.8, 2.3.7

Stress in Electrodeposits. R. A. F. HAMMOND. *Bull. Inst. Metal Finishing*, **4,** No. 2, 145-162 (1954).

Six methods of measuring stress in electrodeposits are described and details of the bent-strip method used by Hammond and the spiral contractometer designed by Brenner and Senderoff. [*Proc. Am. Electroplaters' Soc.*, **35,** 53 (1948)] are given. Stress data for cadmium, cobalt, copper, iron, lead, nickel, rhodium, silver and zinc electrodeposits are tabulated. Effects of changes in bath composition on stresses in nickel deposits are tabulated and graphs are given showing the reduction in fatigue strength caused by the chromium plating of steel. Possible causes of internal stresses in electro-deposits are discussed, viz. co-deposited hydrogen, metal overvoltage, fine grain deposits, crystal form and orientation and organic colloids. Another form of stress, which occurs mainly in zinc deposits, builds up gradually for several days after deposition and is thought to be associated with intergranular corrosion of the zinc. 21 references.—MA. 9131

5.3.2

The Alloy Growth Rate of 0.25 Pound Electrolytic Tin Plate in the Temperature Range 380-440° F. WILLIAM N. LAMBERT. *Corrosion,* **11,** No. 10, 454t-458t (1955) Oct.

Quarter pound electrolytic tin plate was immersed from five seconds to thirty minutes in a constant temperature oil bath at four temperatures below the melting point of tin. The growth of the tin-iron alloy for each temperature and inititl alloy layer was plotted, and from these data an equation was obtained for the rate of growth of the alloy layer. 9701

5.3.2

Treatment and Corrosion Protection of Surfaces by Means of High Vacuum Vapor Metallization. (In German.) WALTER REICHELT. *Z. Metallkunde,* **46,** No. 4, 268-271 (1955) April.

Characteristics and techniques of the process; evaporation and condensation in high vacuum; fields of application. Photographs. Two references.—BTR. 9654

5.3.2

Cadmium or Zinc? O. NIEDERMEYER. *Metalloberflache.* Sec. B., **7,** 39-40 (1955) Mar.

Short note on comparative evaluation of cadmium or zinc plate as surface protection for parts exposed to industrial or marine atmospheres. Exposure tests were made on bright zinc-plated, cadmium-plated and copper-nickel-plated sheets. Details of test method are given. A 5 micron thick cadmium plate is equivalent to an 8 micron thick zinc plate and equivalent to copper-nickel coating of 15 microns. Economic considerations are included. For tropical climate, cadmium-plating should be preferred in spite of higher costs involved. —INCO. 9657

5.4 Non-Metallic Coatings and Paints

5.4.2

Ceramic Coatings for Nuclear Reactors: A Progress Report. J. C. RICHMOND, H. G. LEFORT, C. N. WILLIAMS AND W. N. HARRISON. *J. Am. Ceram. Soc.*, **38,** No. 2, 72-80 (1955) Feb.

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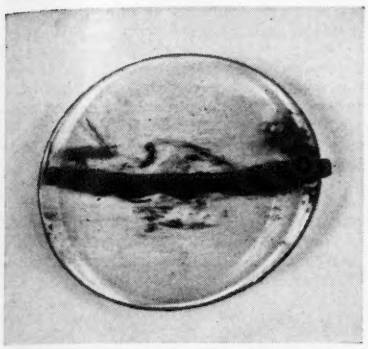

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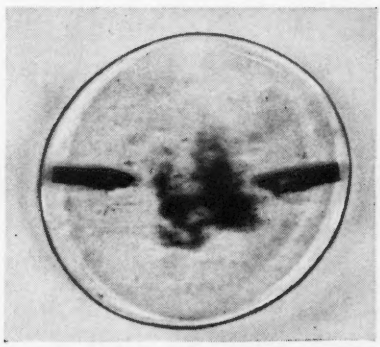
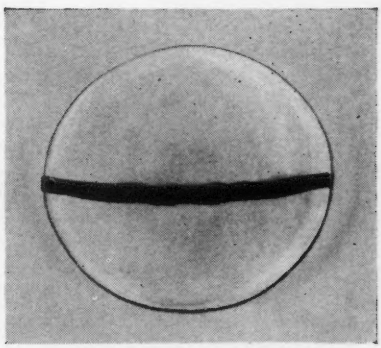
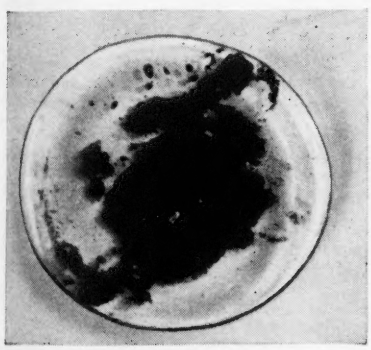


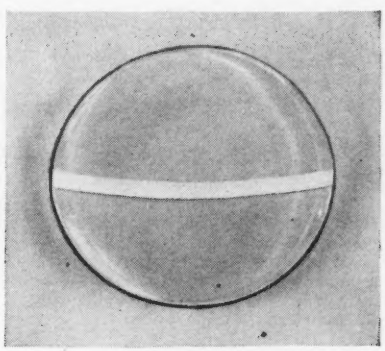
NATURAL RUBBER—10 min. immersion in RFNA



BUTYL—2 hr. immersion in RFNA



GRS—10 min. immersion in RFNA



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200 new coatings for the protection of high-temperature alloys (Inconel, stainless steels, Stellite 25, and Nichrome V) against oxidation were tested. The influence of the method of surface preparation was investigated.—BNF. 9662

5.4.2

Electrophoresis in Jewelry Enameling. N. F. CERULLI. Paper before Am. Ceramic Soc., 56th Ann. Mtg., Chicago, April 19-23, 1954. *Bull. Amer. Ceram. Soc.*, **33**, No. 12, 373-377 (1954) Dec.

The use of electrophoretic deposition is suggested as a jewelry enameling technique. Deposition of three relatively simple enameling glass formulations suitable for copper was effected by covering the electrodes with a suspension of the formulations, containing about 30 mg. of nickel nitrate per 100 cc. of suspension as the electrolyte, and applying the voltage. The particles became positively charged and were deposited on the cathode. The thickness of the coating varied linearly with the time the voltage was applied and optimum coating time varied with the suspension used. If the deposition time continued beyond the point where the current ceased to drop, coatings became rough. Illustrations, graphs, 8 references.—INCO. 9711

5.4.5

Paint Appearance Measurements. Part I.—Reflectance. Part II.—Gloss. Part III.—Colour. E. S. BECK. *Org. Finishing*, **15**, Nos. 3, 4, 5, 9-14, 16-23, 19-25 (1954) March, April, May.

The various instruments used for measuring reflectance, gloss and color are indicated.—BNF. 9798

5.4.5

Reactions at the Iron/Paint Interface and Their Modification by Inhibitors. A. V. BLOM. *Werkstoffe u. Korrosion*, 5, No. 11, 425-430 (1954).

The corrosion of iron and its inhibition by paint are discussed. Topics considered include the corrosion reaction, factors influencing the adhesion of the paint film, and inhibitors.—RPI. 9800

5.4.5

Paint Versus Corrosion. Parts I, II. H. DIAMOND. *Corrosion Technology*, 1, Nos. 4, 5, 97-100; 145-148, 152 (1954) June, July.

In the discussion of industrial paints for the protection and decoration of metal surfaces, the types of paints now available are reviewed, means of application by spraying and dipping are discussed, and how the paint film may be dried is described. Anti-corrosive uses of paint in industry dealing especially with vehicles, refrigerators, kitchen equipment, office equipment, furniture, the oil industry, containers and drums, ammunition, the chemical industry and the aircraft industry, are discussed.—INCO. 9767

5.4.5

Where Asphalt Coatings Are Used. GALE BENN. *Materials & Methods*, **39**, No. 2, 142-144 (1954) Feb.

Application of asphalt as protective coating in its solid and liquid form and in form of dispersions or emulsions. Asphalt emulsions show excellent corrosion resistance under extreme conditions of exposure. Value for insulation protection stressed. Low initial cost of application and extremely long life of material are major advantages of asphalt coatings.—BL. 9783

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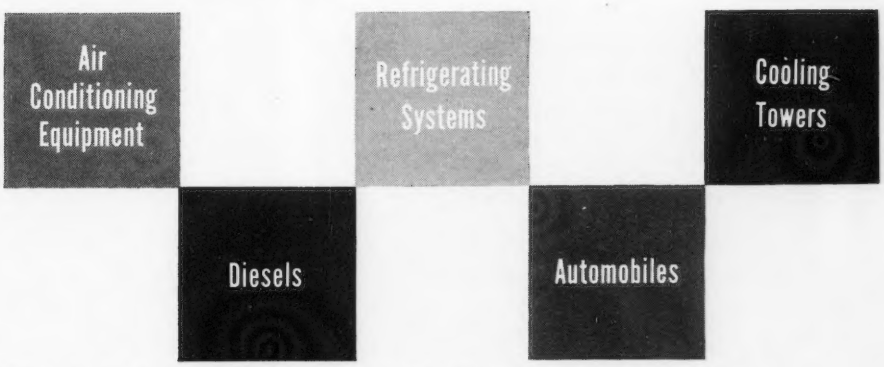

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5.8 Inhibitor and Passivators

5.8.1, 3.6.8
Estimating Inhibiting Power by Means of Polarization Curves. (In Italian.) G. BOMBARA. *Metallurgia italiana,* **46,** special supplement to No. 5, 119-120 (1954) May.

Advantages of method. 1 reference—MR. 9794

5.8.2
Resurgent Corrosion Fighter. *Chemical Eng.,* **62,** 140-142 (1955) Feb.

Solvay re-examines sodium nitrite's properties as a corrosion inhibitor, boosts sales many fold in less than five years. Photograph.—BTR. 9314

5.8.2, 6.4.2, 4.4.7
Silicates as Corrosion Inhibitors in Synthetic Detergent Mixtures. RAYMOND GETTY, NEWTON W. MCCREADY AND WILLIAM STERICKER. ASTM Bull., No. 205, 50-59 (1955) April.

Tests were conducted to determine the degree of corrosion of aluminum with some detergent solutions, and the degree of protection obtained by the addition of various amounts of various silicates. The experimental procedure is described in detail and the results reported. Tests made with aluminum which contained at least 99 percent aluminum, not over 1 percent silicon and iron, and about 0.2 percent copper and 0.10 percent manganese led to the same conclusions as another series of tests made with 3S. It was found that the silicate content of the most popular heavy-duty synthetic household detergents now on the market is sufficient to prevent the corrosion of aluminum.—ALL. 9369

5.9 Surface Treatment

5.9.1, 6.4.2
Chemical Action on Unprotected Aluminium and the Course of the Polishing Process. (In German.) H. GINSBERG AND F. BAUMANN. *Metall,* **9,** No. 5-6, 160-163 (1955) Mar.

The authors conducted comparative investigations concerning the behavior of aluminum samples of various purities and surface treated by various methods in the presence of acetate. The anodically polished surface proved to be the most resistant. The surface chemically treated and especially by the "Erftwerk" method showed a marked tendency to corrode, this latter in one case even proved to be more vulnerable than sand-blasted finishes. As a general result it has been found that the chemically polished surfaces have less resistance to corrosion in the presence of acetate than rolled or mechanical finishes. Thus the application of oxide films to protect these surfaces is recommended.—ALL. 9507

5.9.2, 3.7.3, 6.2.5
Chemical Process of Descaling Stainless and Heat-resisting Steel Without the Use of Acids. B. WENDEROTT. *Stahl und Eisen,* **75,** No. 3, 141-144 (1955) Feb. 10. (In German).

Descaling by treating in a salt bath and annealing subsequently in reducing gases. Effect on the resistance to corrosion and to heat. Pretreatment in a salt bath prior to bright annealing and plating.—SE. 9288

6. MATERIALS OF CONSTRUCTION

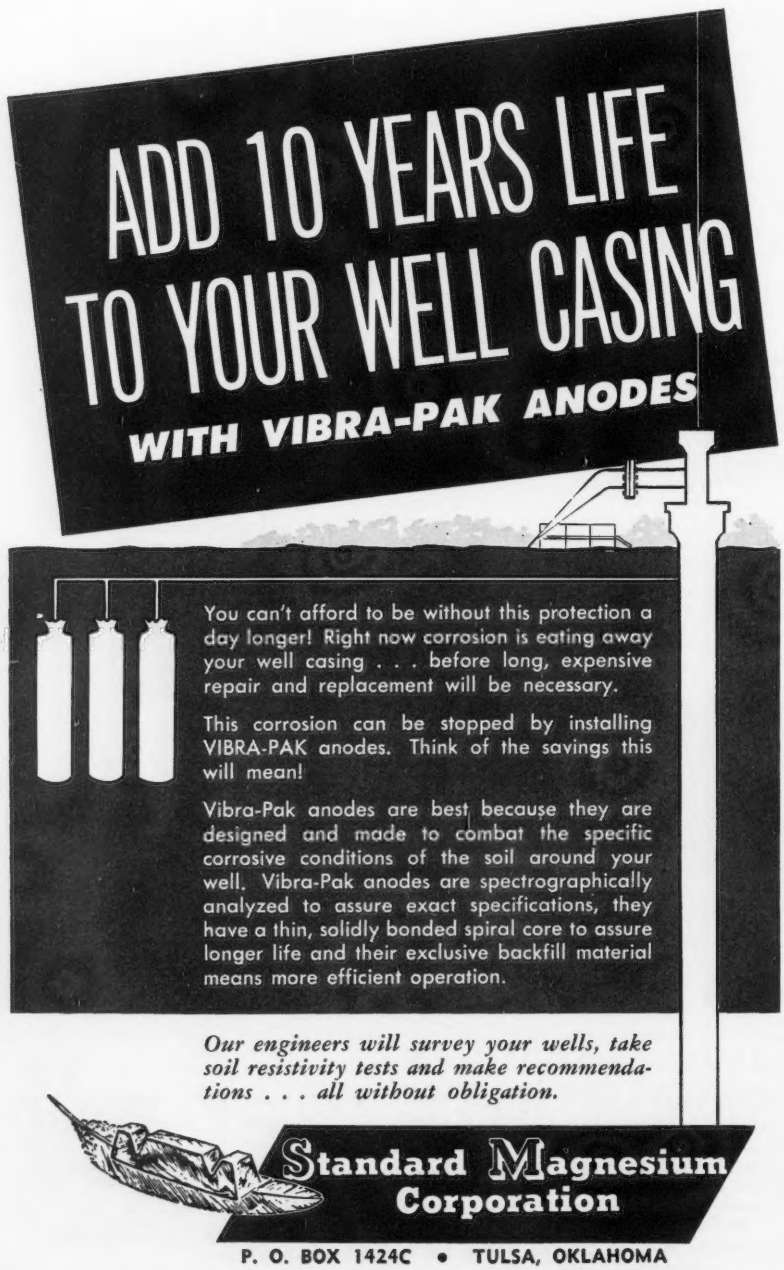
6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.3
The Fabrication of Chromium and Some Ductile Chromium Base Alloys. F. HENDERSON, S. T. QUASS AND H. L. WAIN. *J. Inst. Metals,* **83,** No. 4, 126-132 (1954) Dec.

As-deposited electrolytic chromium of sufficient purity and with an electropolished surface is shown to be ductile at room temperature after heating to 850° C., which removes internal stresses, reduces hydrogen content and produces grain growth in the deposit. This material remains ductile after arc-casting. Arc-melted electrolytic chromium can be fabricated by forging, swaging and rolling; remains ductile after these treatments provided contamination is reduced to a minimum. Alloys of chromium containing 1 percent titanium and up to 5 percent tungsten can be fabricated by the methods used for pure chromium. The products are ductile at room temperature. The technique was not successful with higher alloy contents.—BNF. 9743

6.3.4, 3.5.9
A Statistical Study of the Creep and Fatigue Properties of a Precision-Cast High-Temperature Alloy. G. T. HARRIS AND H. C. CHILD. *J. Iron Steel Inst.,* **178,** No. 3, 284-290 (1954) Nov.

Investigation of alloy G.34 (45 cobalt, 20 chromium, 15 iron, 12 nickel, 2.8 vanadium, 2 molybdenum, 1.2 niobium, 1 manganese, 0.8 carbon, 0.5 silicon), developed for gas-turbine rotor blades. Creep strength at 700-850° C., fatigue strength at 700-870° C. Properties became attrac-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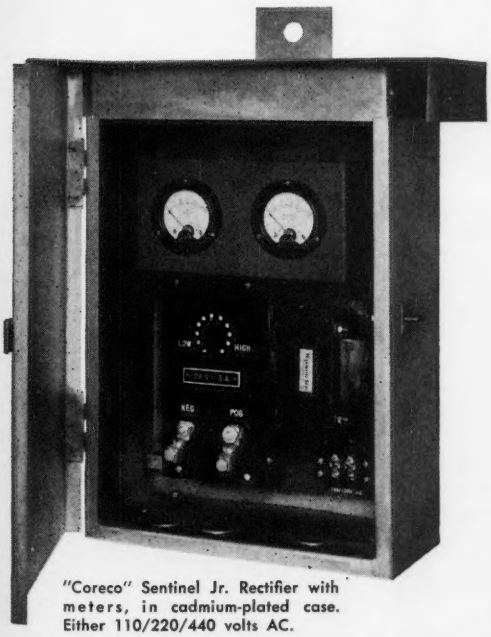

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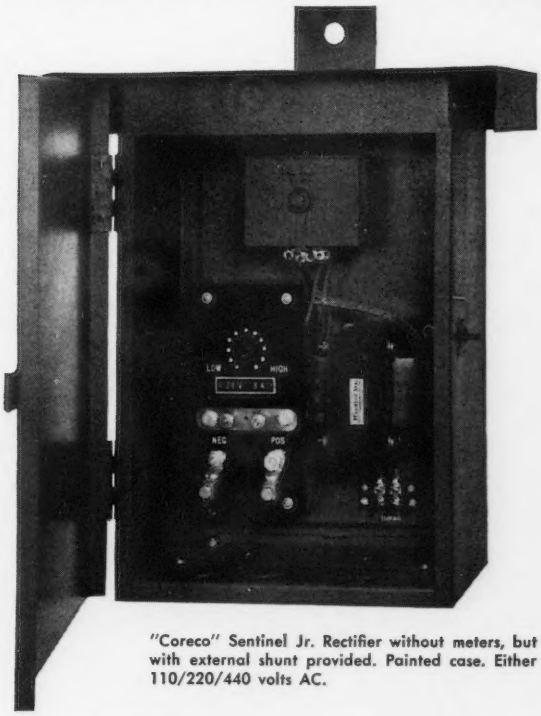

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tive in comparison with existing wrought materials above 800° C.—BNF. 9750

6.3.4, 3.8.2

Electrochemical Behaviour of Cobalt. Potential-pH Diagram of System Co-H_2O at 25° C. (In French.) E. DELTOMBE AND M. POURBAIX. Cebelcor Tech. Rept. No. 6, March, 1954 19 pp. Available from Centre Belge d'Etude de la Corrosion, 21 Rue des Drapiers, Brussels.—BNF. 9777

6.3.5

Columbium (Niobium). G. L. MILLER. *Ind. Chemist,* **31,** No. 361, 100 (1955) Feb.

A letter pointing out that the corrosion resistance of niobium in hydrochloric acid is inferior to that of tantalum. Mentions that Murex, Ltd. have made ductile niobium, and have produced seamless niobium tubing in conjunction with Accles and Pollock Ltd.—BNF. 9598

6.3.6

Isothermal Transformations of Eutectoid Aluminium Bronzes. R. HAYNES. *J. Inst. Metals,* **83,** No. 3, 105-114 (1954) Nov.

The investigation of the reactions occurring during isothermal transformation and the effect of nickel additions. Alloys examined contained 12-15 percent aluminum and 0-8.40 percent nickel.—BNF. 9698

6.3.6

Reaction of Metallic Copper with Copper Mattes. (In Russian.) N. P. DIEV, V. V. PADUCHEV AND A. F. PLOTNIKOVA. *J. Applied Chem., USSR* (Zhurnal Priklad. Khim.), **27,** No. 2, 127-135 (1954) Feb.

Determination of the rates of reaction of copper with ferrous sulfide at 1000° and 1200° C.—BNF. 9782

6.3.6, 6.4.2, 6.3.15, 6.3.11

Non-Ferrous Data for the Chemical Engineer. W. H. L. HOOPER AND N. P. INGLIS. *Chemistry & Industry,* No. 44, 1334-1348 (1954) October 30.

Data on mechanical properties (including low and high temperature), corrosion resistance and fabrication characteristics of copper and alloys, aluminum and alloys, titanium and silver. This paper attempts to fill a few of the gaps in design data and construction requirements which at present prevent, for example, the application of B. S. Code 1500 (fusion welded vessels) to the metals available to the chemical engineer.—BNF. 9731

6.3.6

The Use of Brass and Nickel Silver in the Watch Industry. (In French and German.) W. BRANDT. *Pro-Metal,* **6,** No. 41, 403-410 (1954) Oct.

Desirable properties, effect of impurities, production of the various components and alloys used.—BNF. 9796

6.3.8, 3.8.2

Contribution to the Knowledge of Corrosion of Lead in Distilled Water. (In German.) T. MARKOVIC. *Werkstoff u. Korrosion,* **6,** No. 3, 133-135 (1955) Mar.

Investigation of effect of rate of diffusion of oxygen by potential/time measurements; with increasing depth of immersion the potential of the lead electrode becomes nobler. Experiments also on cathodic polarization of lead in distilled water, in which it is found that H^+ ions on discharge are not converted directly to gas, but first form adsorbed hydrides of lead.—BNF. 9611

6.3.8, 4.5.1

On the Passive and Active Behavior of Lead in Soils. T. MARKOVIC AND Z. DUGI. *Werkstoffe u. Korrosion,* **6,** No. 6, 294-296 (1955) June.

Conditions for the corrosion of lead in soils are mathematically calculated, depending on the water-air-contents-ratio. The loss of weight of active lead follows an exponential law while that of passive lead follows a linear law. Lead shows passive behavior in numerous soils. It becomes active due to HCO_3 ions. The metal is passive in soils in carbon dioxide atmospheres.—INCO. 9587

6.3.9, 5.4.2, 1.6

The Properties of Oxidation Resistant Scales Formed on Molybdenum-Base Alloys at Elevated Temperatures. Technical Report No. 467-3. M. GLEISER, W. L. LARSEN, R. SPEISER, AND J. W. SPRETNAK. Research Foundation, Ohio State Univ., Contract N6onr-22528, Feb., 1955, 50 pp.

Due to the limitations of externally applied claddings for protectiong molybdenum-base alloys from oxidation at elevated temperatures, a program of developing protective self-regenerative scales on molybdenum-base alloys was conducted. Various molybdates and molybdenum-containing oxide complexes were tested for stability at elevated temperatures. Nickel and cobalt molybdates appeared promising and were further studied in terms of their properties and their ability to form as protective scales upon molybdenum alloys containing them. Results of oxidation tests show that molydate scales will form on molybdenum-nickel and molybdenum-

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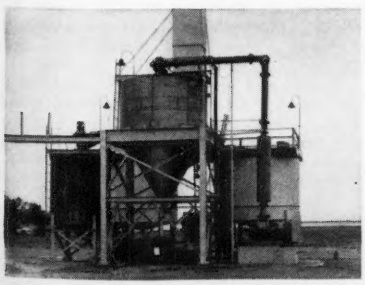

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cobalt alloys and are protective. Both nickel and cobalt molybdates spall upon thermal cycling. Spalling can be suppressed by the addition of certain third components which stabilize the molybdate crystal structure. The nature and suppression of spalling are discussed. 24 references. (auth.)—NSA. 9409

6.3.10

Heat-Resistant Nickel-Chromium Alloys for Gas Turbines and Other Industrial Applications. J. O. HITCHCOCK. Paper before Soc. Roy. Belge, Ing., May 5, 1954. *Rev. Soc. Roy. Belge. Ing.*, No. 9/10, 1954, 16 pp.

Covers properties of materials for gas-turbine components including properties of Nimonic alloys—Nimonic 75, Nimoply 75, Nimonic 80, 80A, 90, 95, F, DS, DT. Internal-combustion engine (piston) components, extrusions, Nimonic 80 nuts, bolts, etc., conveyor belts for furnaces, heat-treatment plant, and glassworks equipment are discussed.—INCO. 9724

6.3.10

Creep of High Purity Nickel. W. D. JENKINS, T. G. DIGGES AND C. R. JOHNSON. *J. Res. Nat. Bur. Stand.*, **53**, No. 6, 329-352 (1954) Dec.

Study of the influence of stress, temperature and prior strain history on creep behavior of initially annealed high purity nickel: temperature studies at 149°, 371°, 482° and 649° C. Discontinuous flow was observed in each of the three stages of creep at all temperatures: the phenomenon of strain ageing especially prominent in tests at 149° C. Effect of prestraining in creep on the mechanical properties at room temperature, including yield, tensile properties and hardness. Experimental results emphasize the importance of the rate of loading in creep tests.—BNF. 9739

6.3.10, 3.5.9

Effects of High-Temperature Oxidation on the Surface Composition of a Nickel-Chromium-Titanium-Aluminium Alloy. (In French.) FRIMA MALAMAND AND GEORGES VIDAL. *Compt. rend.*, **240**, 186-188 (1955) Jan. 10.

Using methods developed by Malamand, an alloy of Nichrome type containing 76 nickel, 19.7 chromium, 2.4 titanium, 1.5 percent aluminum, was examined after oxidation in air at 700, 750, 850 and 900° C. for 300 hours. Compositions were determined spectrographically at the surface and at various depths (after electrolytic polishing). The surface was found to be markedly depleted in titanium and aluminum.—INCO. 9592

6.3.13, 5.9.4

The Optical Properties of Thin Oxide Films on Tantalum. A. CHARLESBY AND J. J. POLLING. Atomic Energy Research Establishment. *Proc. Roy. Soc.* (London), Sec. A, **227**, 434-447 (1955) Feb. 8.

The irridescent colors produced at the surface of anodically oxidized tantalum have been studied spectrophotometrically. These colors result from interference, the intensity of the reflected light varying between certain maximum and minimum values according to the wave length. From measurements of the wave-lengths at which the minima occur, from 2600 to 8500 Å, the refractive index and its variation with wave-length are deduced. Values are 2.84 at 3000 Å and 2.42 at 8000 Å. The phase change at the metallic surface was also deduced, values being 0.2π radian at 2700 Å and 0.8π radian at 8000Å. The thickness of the anodically formed films has been found to be 16.0 Å/V. (auth.)—NSA. 9439

6.3.15, 3.7.3, 3.7.4

How Notch Sensitive are Titanium Alloys? F. R. BROTZEN, E. L. HARMAN, JR. AND A. R. TROIANO. *Iron Age*, **174**, No. 27, 52-55 (1954) Dec. 30.

Effect of heat treatment and microstructure on the notch sensitivitives of two commercial alloys (titanium-0.6 percent vanadium and titanium-2.5 percent vanadium). Results are compared with properties of aluminum alloy (75S-T) and stainless steel (AISI 310).—BNF. 9786

6.3.15, 3.7.3

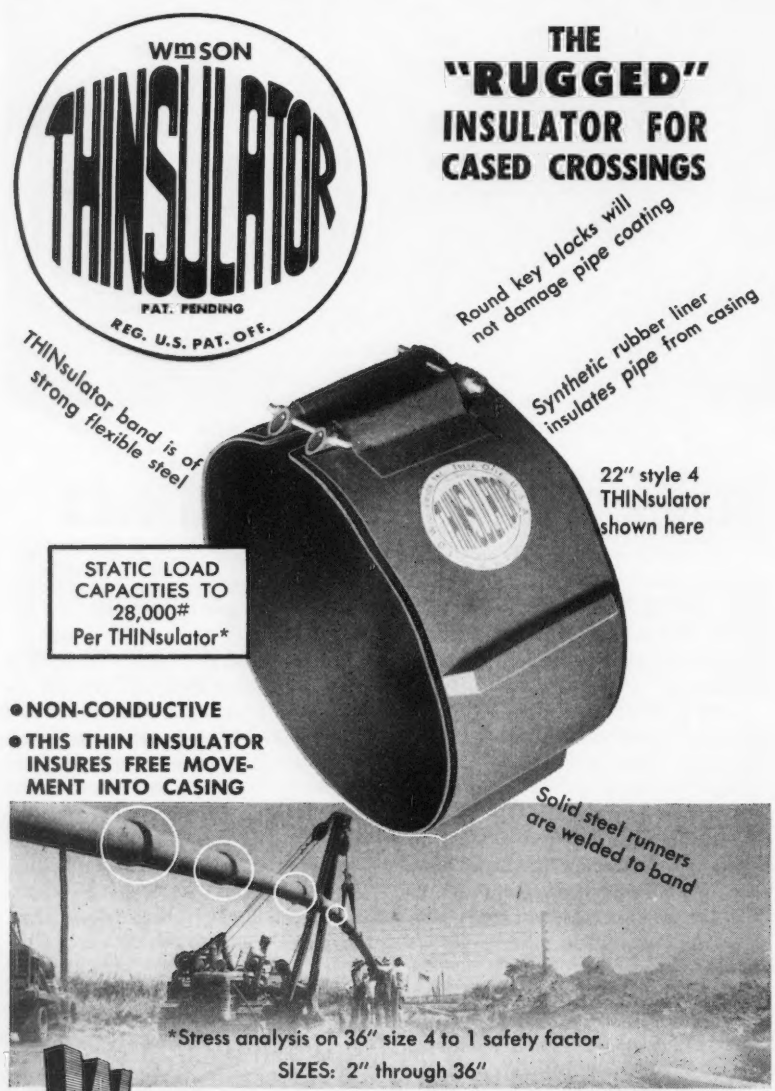
New Techniques for Titanium: Development of Cutting, Forming and Assembly Methods. R. L. HAVER AND D. S. ADAMS. *Welding and Metal Fabrication*, **22**, No. 10, 368-373 (1954) October.

Techniques developed by Ryan Aeronautical Co. Use of titanium rivets, special drills developed for titanium, blanking, grinding, cutting, hot and cold forming, sigma welding (gives weld strength data).—BNF. 9740

6.3.15

Low-Temperature Impact Properties of Titanium. D. E. DRISCOLL. Am. Soc. Testing Materials Special Tech. Pubn. No. 158, September 1954, 326-331.

Paper presented at A.S.T.M. annual meeting, June, 1953. Notched Charpy impact tests between —200° and 700° C. on titanium and titanium alloyed with manganese, magnesium-aluminum and iron-chromium. Purity and composition of materials not given. Results discussed in terms of transition temperature and tensile properties.—BNF. 9764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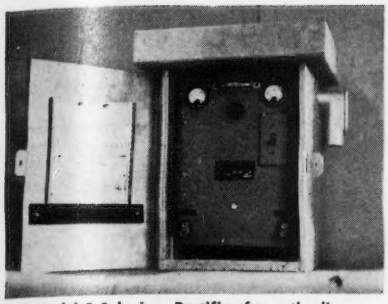

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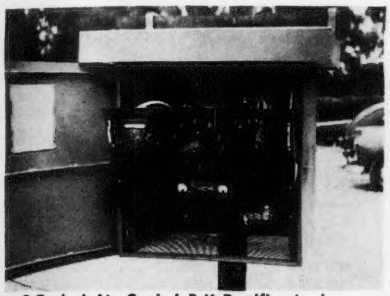

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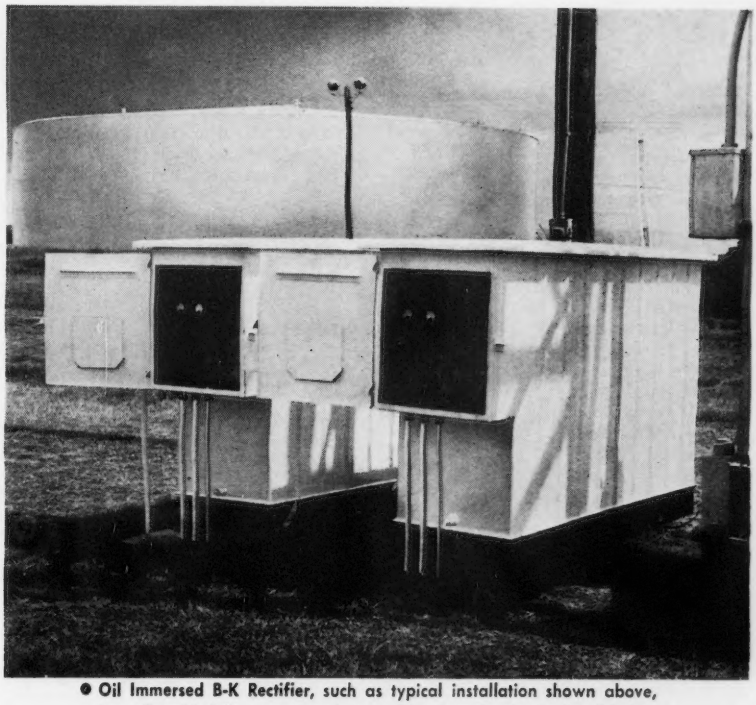

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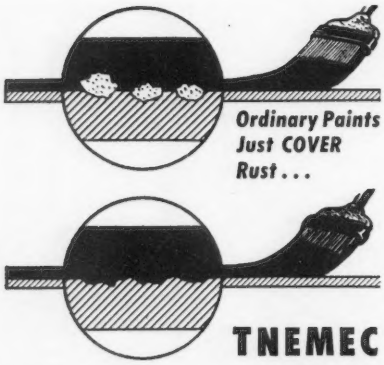

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6.3.15

Titanium—Its Progress and Applications. T. E. PERRY AND R. J. GARMY. *Iron Steel Engr.*, **32**, No. 2, 98-105; disc., 105-106 (1955) Feb.

After approximately six years of industrial development, titanium production has reached a level of 4-5 thousand tons annually. Rutile (TiO_2) and ilmenite ($FeTiO_3$) are common titanium ores. Fundamentals of extractive metallurgy are reviewed. Principal use of titanium today is in top priority high speed aircraft, while its excellent corrosion resistance and high strength to weight ratio are responsible for increasing usage in chemical plant equipment, food processing lines, orthopedic devices, anodizing racks and other non-military applications. A representative cross-section of some commercially available titanium grades is tabulated showing physical constants and wide range of properties available. A reference guide to melting techniques and procedures for titanium is presented. Diagrams, tables, graphs.—INCO. 9607

6.3.21, 6.6.9, 6.3.13, 6.3.5, 6.3.20

Production and Uses of Germanium, Pure Silicon, Tantalum, Niobium, and Zirconium.—CHEVIGNY AND ROY. *Metaux, Corrosion-Industries*, **29**, No. 345, 181-189 (1954).

The physical and mechanical properties, gettering behavior, corrosion-resistance, and working of these metals are reviewed at some length. Uses are discussed, with special reference to the electrical field. No new uses are mentioned. The metals are currently produced in France, but are not yet in wide demand.—MA. 9702

6.3.21

Effect of Various Etchants on Germanium. Part I. Chemical Action of Various Agents. Part II. Physical Considerations. (In German.) O. ROSNER. *Z. Metallkunde*, **46**, No. 3, 225-229, 229-233 (1955) Mar.

Part I covers the treatment of Germanium surfaces with various agents to remove impurities, etc., and for metallographic purposes, including action of water, inorganic and organic acids, sodium hypochlorite, hydrogen peroxide, per salts, carbon dioxide and chlorine; and recovery of germanium from etching solutions. Part II deals with effects on electrical resistance behavior.—BNF. 9670

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2, 3.5.8, 2.3.7

Fatigue Tests at Stresses Producing Failure in 2 to 10,000 cycles. H. F. HARDRATH AND W. ILLG. U. S. National Advisory Committee for Aeronautics, Tech. Note No. 3132, Jan., 1954, 13 pp.; Available as PB.112, 793 from Dept. Sci. Ind. Research, Technical Information and Documents Unit, 15 Regent St., London, S. W. 1, for inspection, loan or provision of photocopies.

24S-T3 (aluminum—4.5 percent copper—1.5 percent magnesium) and 75S-T6 (aluminum—6 percent zinc—3 percent magnesium—2 percent copper) aluminum alloy sheet specimens with a theoretical stress-concentration factor of 4.0 subjected to completely reversed axial load.—BNF. 9700

6.4.2, 7.1

Light Alloy Pistons and Their Importance in the Aluminium Industry. (In German.) E. MAHLE. *Aluminium*, **31**, No. 2, 70-74 (1955) Feb.

Surveys growth and development of use of aluminum alloy pistons: use of high silicon alloys, die-casting and press forging, SAP, machining, surface treatment, pistons with steel inserts.—BNF. 9604

6.4.2, 3.7.2

Influence of Impurities on the Hot Strength of Aluminium. (In Russian.) A. A. BOCHVAR, Z. A. SVIDERSKAYA AND L. M. KYCHAKOVA. *Bull. Acad. Sci. USSR* (Izvestiya Acad. Nauk SSSR), Chemical Sciences Section, No. 2, 46-51 (1954) Feb.

Measurement of hardness of as-cast and stabilized specimens of six grades of aluminum (99.28-99.99 percent aluminum) at room temperature and at 300° C. Gives curves showing the softening at 300° C.

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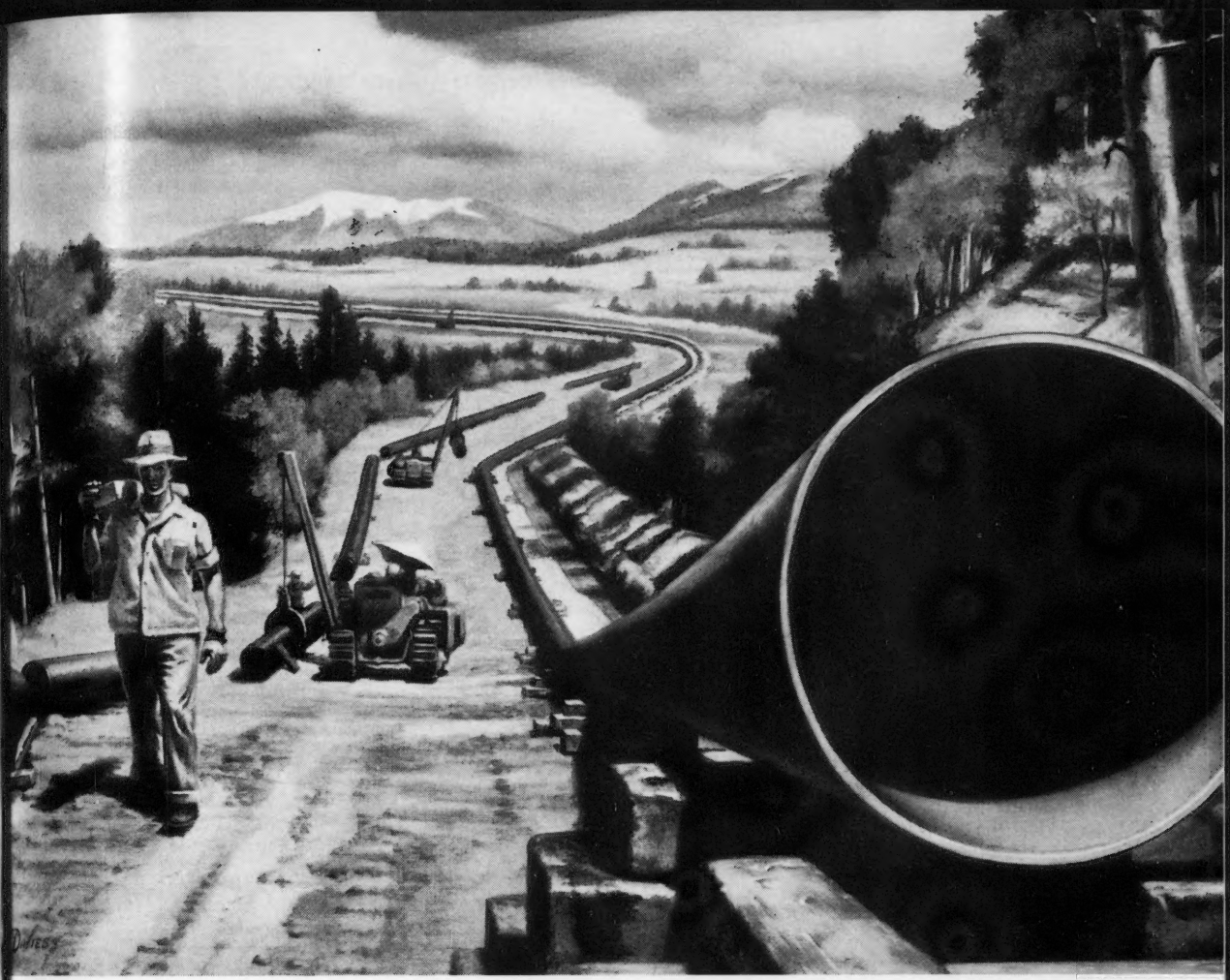

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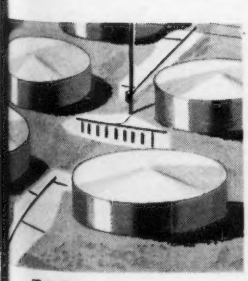

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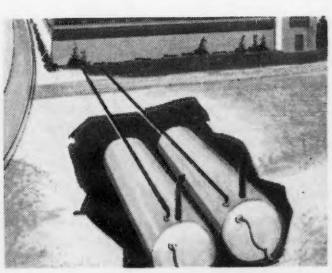

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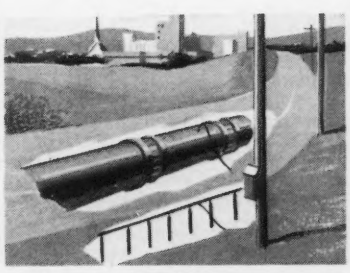

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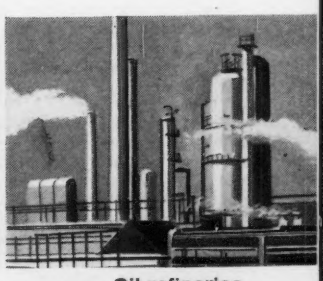

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6.4.2, 3.7.3

Research on the Electro-Chemical Properties of Aluminum-Magnesium Alloys. Part V. HIROMITSU HARIMOTO AND KATSUZO MIZUNO. *Light Metals* (Japan), No. 10, 67-71 (1954) May.

The electrochemical properties of 56S were studied. The chemical composition of the aluminum was silicon 0.15 percent, iron 0.14 percent, copper trace, zinc trace, manganese 0.16 percent, magnesium 5.6 percent, chromium 0.11 percent, and aluminum 93.84 percent. The electrolytes 0.5 percent sulfuric acid and 0.1 percent sodium hydroxide were used. For sulfuric acid, there was very little difference in the change of potential and a slight difference in the change of current. For sodium hydroxide, the results were similar. In each case, the change of potential and current was of greater value when the samples were tempered at 200° C. It is thought that these phenomena were due to the changes of internal structure.—ALL. 9745

6.4.2, 3.7.3

Research on the Electro-Chemical Properties of Aluminum-Copper Alloys. Part II. HIROMITSU HARIMOTO. Light Metals (Japan), No. 12, 60-63 (1954) Aug. 31.

This paper deals with the relationship between ageing and the Vicker's hardness and potential of Duralumin (17S). The samples were water quenched from 505° C. and then tempered at 130, 165, 190, 220, 240, 260, 280 and 300° C. After heat-treatment, they were dipped in an electrolyte of 3 percent sodium chloride and then the electrode potential was measured by the Valve-voltmeter. A relationship was found between ageing and hardness, potential and the hydrogen evolution.—ALL. 9747

6.4.2, 3.7.3, 1.6

The Riveting of Aluminium. A.D.A. Information Bull. No. 8, revised Sept., 1954, 62 pp. Published by Aluminium Development Association, 33 Grosvenor St., London, W. 1.

Revised and up-to-date version of the 1944 edition. Gives data on rivet materials; sizes and head shapes and manufacture; design of riveted joints; riveting light assemblies and large structure (equipment, preparation, rivet point shapes, driving and inspection of joints). Appendices are given on standard nomenclature; mechanical testing of rivets; heat-treatments of aluminum rivets; and length of rivets. 20 references.—BNF. 9781

6.4.4, 5.4.5

Research Investigation of Protective Coatings for Magnesium. H. D. CHILDERS, K. B. NILES AND A. G. VALLES. U. S. Wright Air Development Center, Tech. Rept. 52-99, 1952 (unclassified 1954), 20 pp. (on micro-cards).

A study was made of a number of organic protective coatings applied to magnesium and its alloys in an effort to minimize its susceptibility to aqueous corrosion; the properties of electrical insulation, alkali resistance, and adhesion of the coatings were studied. The following generalizations were reached. Baked films were not significantly more protective than air-dried films; as the former had better adhesion, it is concluded that this is not a critical property in magnesium protection. For a non-perfect film, which is true of nearly all production-painted assemblies, an inhibiting pigment is essential for superior performance. The more satisfactory coatings were of polyvinyl chloride or a copolymer of vinyl chloride-vinyl acetate with suitable additions to modify adhesion, flexibility, etc. It is not sufficient to regard coatings of low acid number as essential, as this property must be considered in relation to the permeability and degree of perfection of the coating; where the latter is poor a low acid number is beneficial. Furthermore, a study was made of the most suitable pretreatment of the surface. In accelerated sea-water corrosion tests it was found that many of the coatings were extremely sensitive to the effect of temperature and degree of solar radiation, a 10° F. (5° C.) increase in temperature causing a pronounced increase in the rate of corrosion.—MA. 9755

6.4.4, 5.11, 1.6

Magnesium Design Notes. Brochure, 1954, 136 pp. Dow Chemical Co., Magnesium Dept., Midland, Michigan.

Data on physical and mechanical properties and special characteristics of magnesium and magnesium alloys; structural design with magnesium alloys; product design for magnesium castings, extrusions, sheet and plate; machining, forming and jointing (including various welding processes); protection of assemblies (e.g., joints of magnesium to magnesium; magnesium to other metals and magnesium to wood); surface stability and finishing.—BNF. 9768

6.4.4, 2.2.2

Results of Some Marine-Atmosphere Corrosion Tests on Magnesium-Lithium Alloys. P. D. FROST, F. W. FINK, H. A. PRAY AND J. H. JACKSON. *J. Electrochem. Soc.*, **102**, 215-218 (1955) May.

Magnesium-lithium binary alloys which contain just enough lithium (about 11 wt. percent) to produce a single-phase, body-centered cubic structure have shown surprisingly good resistance to corrosion in 3 percent salt solution. high-strength alloys having about 9 percent lithium and various quantities of aluminum, zinc, and other elements have a mixed hexagonal-plus-body-centered cubic structure. Such alloys generally have poorer corrosion resistance than the single-phase binaries. Three of the high-strength alloys were exposed for 32 months to the sea-coast atmosphere near Daytona Beach, Florida. For comparison purposes, samples of commercial AZ31A-H24 alloy were exposed at the same time. All alloys were in the form of 4 x 6 x 0.064 in. panels. The AZ31A sheet had corrosion resistance only slightly superior to that of an alloy containing magnesium—8.7 percent lithium—5 percent aluminum—8 percent zinc. The other two alloys, magnesium—8.8 percent lithium—7 percent aluminum—0.05 percent tin—1 percent manganese and magnesium—8.8 percent lithium—7 percent aluminum—1 percent tin had much poorer corrosion resistance. 9371

6.4.4, 3.7.2

Effect of Very Small Amounts of Beryllium in Magnesium Alloys. (In German.) K. E. MANN. *Z. Metallkunde*, **46**, No. 1, 17-24 (1955) Jan.

Preparation of magnesium-aluminum-beryllium alloys using an aluminum-beryllium master alloy. Addition of up to 0.01 percent beryllium renders the molten alloy more stable to air (removal of sulfur), lowers tendency to porosity and permits use of unprotected moulding sand; cast or extruded parts may be annealed without use of protective atmosphere. Tensile properties in the as-cast condition are not affected, but in the annealed condition tensile strength decreases with increased berylliunm content. Corrosion properties of magnesium-aluminum alloys are not influenced unless the iron content is high.—BNF. 9589

6.4.4, 5.9.4, 1.6, 2.3.6, 2.3.5

Fundamental Study of Natural and Synthetic Films on Magnesium and Its Alloys. Dow Chemical Co. Wright Air Development Center, Tech. Rept. 54-222, August, 1954, 167 pp.

Techniques for the study of films which are formed on magnesium during surface treatments or corrosion are described. Among the techniques described are electrical resistance measurements on isolated films and on surface-treated electrodes during aqueous exposures, anodic polarization studies on magnesium alloys in inhibited electrolyte systems, and the microstructural study of surface treatment and corrosion films. Many of the properties of a film become understandable when the microstructural details of the film are known. Thus the hardness and abrasion resistance of the Dow No. 14, Dow No. 17, and H.A.E. films are related to their partial vitrefication during the anodic treatment. By way of contrast, the Dow No. 7 film is a thin, smooth layer of a hydrous gel. Because of its structure it is susceptible to electrolytic permeation and to dehydration. Inadequacies in the protective abilities of the hydroxide films on magnesium stem from the spontaneous exfoliation of these films. Chromate ion inhibits the corrosion of magnesium by engendering the formation of a film which does not exfoliate. (auth).—NSA. 9780

6.6 Non-Metallic Materials

6.6.5, 6.2.3

Concrete and Corrosion. T. D. ROBSON. *Corrosion Technology*, **2**, No. 3, 66-70, 96 (1955) Mar.

Corrosion of concrete and factors causing or preventing it present as complex a problem as metallic corrosion and the two are frequently interrelated. Vast tonnage of steel in all kinds of structures is protected by concrete from corrosion. Various types of cement used in concrete, and a description of the chemical agents which can corrode concrete, such as organic acids and sulfates, are considered. Concrete as a means of preventing corrosion and also as a corrosive agent is examined.—INCO. 9663

6.6.6, 8.5.2

Corrosion of (Glassmelting) Tank Blocks in the Light of Research and Plant Experience. R. RASCH. *Glass-Email-Keramo-Tech.*, **5**, No. 9, 313-322 (1954); *J. Am. Ceram. Soc., Ceram. Abs.*, **38**, No. 2, 31 (1955) Feb.

Differences in refractory properties of kaolin and fire clay are explained by differences in lattice structure of kaolinite and "fire-clay mineral." General reactivity of refractory toward molten glass is determined by degree to which the surface exhibits an imperfect lattice. Lattice imperfections increase in number as the melting point is reached, and erosion by the molten glass begins at these points. Temperature gradient through the refractory wall also has a marked effect on extent of the corrosion by glass. 13 figures, 53 references.—INCO. 9635

6.6.7, 5.4.5

Neoprene Notebook No. 60. Brochure, August, 1954, 8 pp. Products Information Service, E. I. du Pont de Nemours & Co., Inc., Wilmington, Delaware.

The seventh in "Language of Rubber" series telling how rubber industry runs tests and what results mean to engineers and designers of rubber parts. Resistance of rubber to abrasion, flex fatigue and tearing are discussed. Neoprene coatings, hog drive belts and safety soles are presented. Also included are Neoprene abstracts on centrifugal pump, leveling mount and cleat conveyor belt. 9766

6.6.7, 1.6, 5.4.3

What Every Engineer Should Know About Rubber. W. J. S. HAUNTON. Book, 1954, 128 pp. British Rubber Development Board, Market Buildings, Mark Lane, E. C. 3, England.

This book discusses the agricultural aspects of rubber, engineering applications, properties, rubber technology, uses of rubber in engineering, and under a heading "Resistance to Corrosion and Chemical Attack", says in part "The outstanding resistance of rubber which is a hydrocarbon (and therefore chemically inert) to attack by chemicals other than solvents, oxidizing and halogenating agents, has led to its wide use in lining chemical plant." Details of uses in lining vessels are given. There is an alphabetical subject index. 9742

6.6.11, 7.5.5

Wooden Vats for Corrosive Liquids. W. T. COLYER. *Corrosion Technology*, **1**, No. 10, 379-381 (1954) Dec.

Properties and applications of wood as a material for vat construction are described. Apart from nitric and hydrofluoric acids and caustic in concentrated form, the great majority of acids and other corrosive liquids in their dilute forms as normally used in industry can be satisfactorily contained in wooden vats. Majority of processes for which wooden vats are used in chemical industry are at or near boiling temperature. Variety in construction of wooden vessels, their cost, and suitable woods are covered.—INCO. 9775

7. EQUIPMENT

7.6 Unit Process Equipment

7.6.6

Status of Digester Corrosion in the South. R. W. MIZELL AND C. W. SMITH. *Paper Mill News*, **77**, 12-13, 16 (1954) April 24.

Review of literature. 12 references.—BTR. 9162

7.7 Electrical-Telephone and Radio

7.7, 8.9.4

Resistance Materials and Braking Safety in Railway Carriages. (In German). H. HOPPE. *Metall*, **8**, No. 17/18, 691-694 (1954) September.

For resistance materials in the electric braking circuit of electric trains, high electrical and wear resistance and low thermal conductivity are required; chromium-aluminum-iron alloys and chromium-nickel-iron alloys are considered.—BNF. 9182

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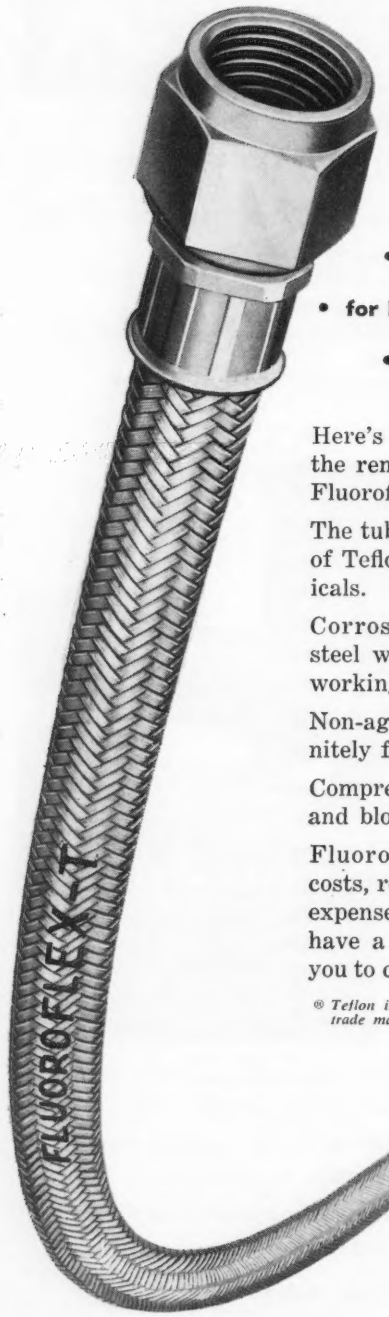

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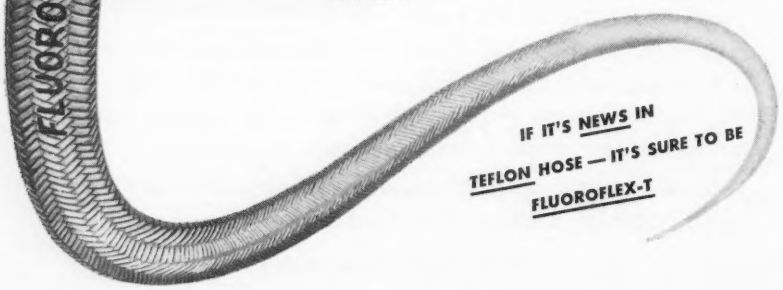

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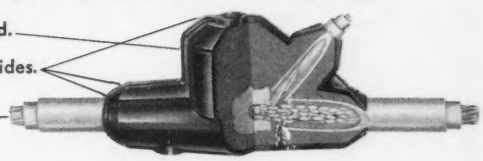
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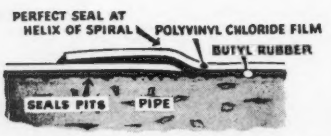

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3. HIGHEST SHOCK-IMPACT RESISTANCE . . . Made of tough polyvinyl chloride film laminated to butyl rubber, Plicoflex Tapes offer the extra protection of more-than-double thickness together with resiliency which prevents damage during backfilling operations.

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5. UNIFORM THICKNESS...Rigid factory inspection assures the user that the Plicoflex system of coatings will be of uniform quality and uniform thickness. Thus the user knows he can depend on Plicoflex to give equal all-over protection.

6. SELF-HEALING PROPERTIES...The cold-flow characteristics of butyl rubber provide another bonus, flowing into and sealing holidays that may occur in the tape film due to mechanical damage.

7. BUILT-IN COLOR-CODING... Available in black, white, and 6 brilliant colors, Plicoflex Systems provide a virtually maintenance-free method of color coding for above-ground plant installations. No painting required – the color is *in the tape!*

8. LOW COST... Unique Plicoflex application systems cut coating manpower requirements to a minimum. You benefit from lower first cost as well as lower maintenance costs.

9. ADHESIVE PRIMERS . . . Factory-produced to thoroughly tested formulae and rigidly inspected for quality and uniformity, Plicoflex adhesive primers are available to suit practically every normal requirement.

10. EXPERIENCE . . . Plicoflex systems have been engineered and produced by men long experienced in corrosion protection of pipelines. **This is our primary interest — not a by-product of other interests.**

Let your Plicoflex representative show you how you can put these PLICOFLEX PLUS VALUES to work for you . . . today! Or write for Plicoflex Data File.

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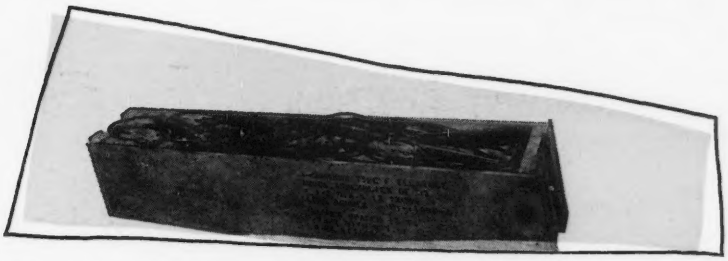
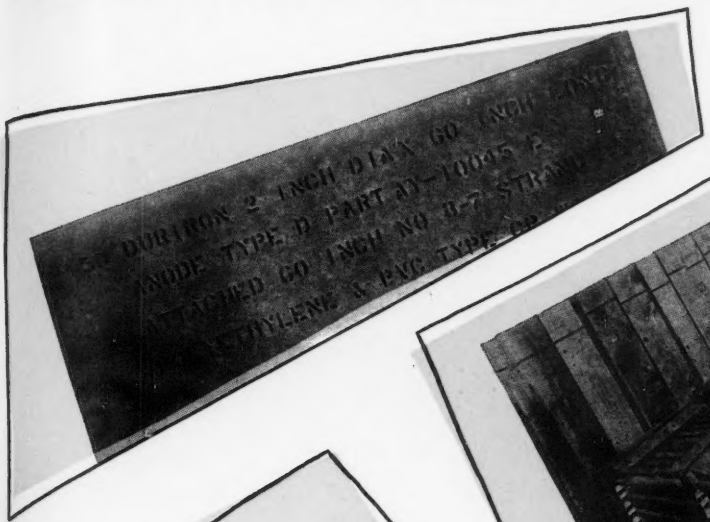
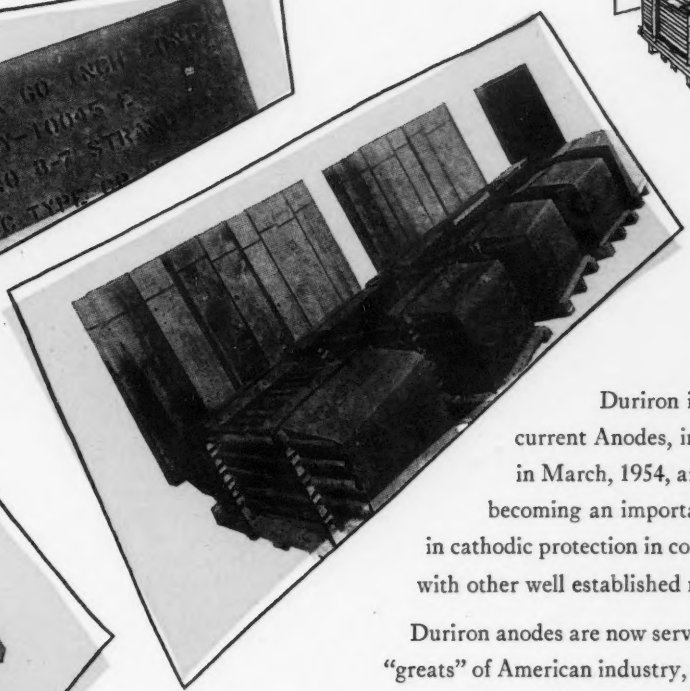
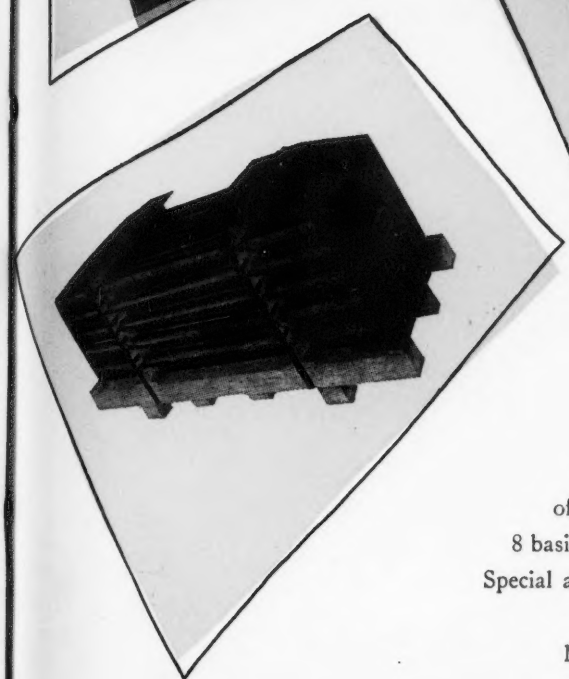


MORE THAN 10,000 IN 10 MONTHS







Duriron impressed current Anodes, introduced in March, 1954, are rapidly becoming an important factor in cathodic protection in competition with other well established materials.

Duriron anodes are now serving many "greats" of American industry, as well as government and municipalities. Installations include piers, pipelines, underground cables, clarifiers, tanks and many others.

Performance? Field performance confirms laboratory data on rate of consumption, contact resistance and maintenance of electrical properties. Duriron Anodes are available from stock in 8 basic designs. These include 1″, 1½″, 2″ and 3″ diameters x 60″ long. Special anodes, 1½″ x 12″, are available in flexible assemblies for use in underground ducts, fresh water tanks and other applications where length is important. Modifications of basic designs are also available.

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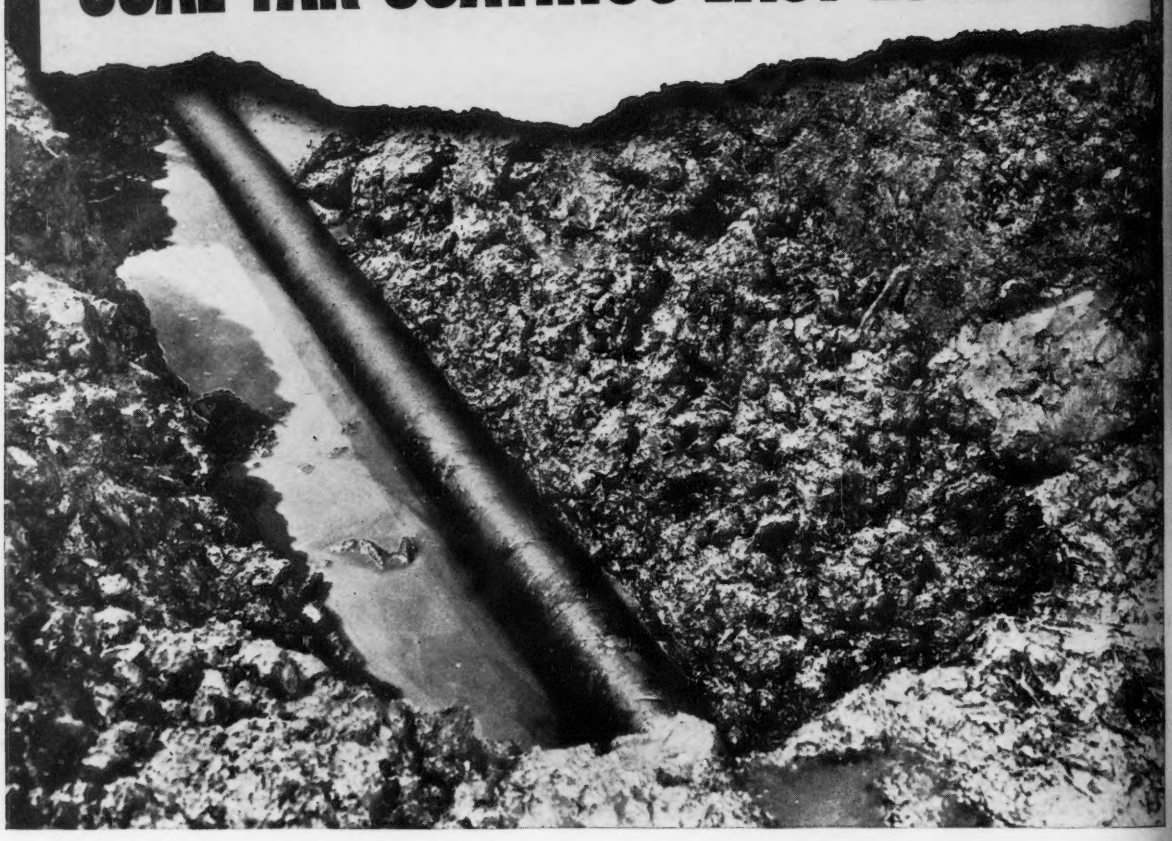
HERE'S 23 YEARS OF PROOF THAT COAL TAR COATINGS LAST LONGER!



THIS coal tar-protected pipeline was buried 23 years in soil permeated with salt water and industrial refuse. But when it was unearthed for inspection, the coating showed no signs of deterioration or failure of any kind!

Isn't that the kind of *proven* protection *you* want? It's the kind of protection you *get* when you specify *Pitt Chem* Coal Tar Pipeline Coatings. For these coatings have demonstrated their tremendous ability to resist soil stress and water absorption—the two principal reasons why "economy" coatings eventually fail.

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